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Nationwide Urban Runoff Program Lake Quinsigamond Urban Runoff Project: Watershed Management Plan for Lake Quinsigamond and Flint Pond (Worcester, Shewsbury, Grafton, Millbury, Boylston and West Boylston, Massachusetts)

Massachusetts Dept. of Environmental
Quality Engineering, Boston

Prepared for

Environmental Protection Agency, Washington, DC

Apr 82

U.S. Department of Commerce
National Technical Information Service
NTIS

PB84-212125

WATERSHED MANAGEMENT PLAN

FOR

LAKE QUINSIGAMOND AND FLINT POND
(Worcester, Shrewsbury, Grafton,
Millbury, Bolyston and West
Boylston, Massachusetts)

Prepared by

Massachusetts Department of Environmental Quality Engineering
Office of Planning and Program Management

And

Massachusetts Division of Water Pollution Control
Technical Services Branch
Lakes Section

Joseph M. McGinn, Project Engineer
Principal Investigator

April 1982

This report was prepared with the assistance of the U.S. Environmental Protection Agency through grants to the Massachusetts Department of Environmental Quality Engineering under the Nationwide Urban Runoff Program and the 314 Clean Lakes Program.

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10

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INTRODUCTION

Since the days of the first settlers in Central Massachusetts, Lake Quinsigamond has been regarded as perhaps the most significant natural resource in the region and one of the most significant in the State. The lake and its surrounding area were host to an abundant variety of fish and wildlife in addition to providing the early settlers with an "unlimited" source of clean water for drinking, bathing and recreation.

Today, in the 1980's, Lake Quinsigamond remains a unique natural resource providing recreational opportunities and a major source of water supply for a region inhabited by over 1½ million people. However, since the early part of the 20th Century, the region has undergone rapid urbanization, industrial development and increasing population all of which have affected the lake and its tributaries. Due to the effects of such rapid urbanization, many of the desirable uses of the lake have been impaired due to gradual degradation of water quality in the lake. Effects have included declining fisheries population, necessitating regular trout stocking; prohibition of swimming due to bacterial contamination; occasional growth of nuisance aquatic vegetation; regular occurrences of algae "blooms," and; limiting use of the lake as a source of water supply for the surrounding communities.

In an effort to more clearly understand the response of the lake system to changes brought about by man's activities within the watershed, the Commonwealth of Massachusetts, with the assistance of the U.S. Environmental Protection Agency, has undertaken two major environmental programs. The Division of Water Pollution Control is conducting a Diagnostic/Feasibility Study of the lake under the EPA, Section 314 Clean Lakes Program.* The objectives of this program are to define the water quality conditions encountered in the lake; to determine the cause/effect relationships between the lake's water quality and sources of water pollution and to recommend actions required to control or alleviate sources of pollution.

---

* Section 314, Public Law 92500 and 95-217

The Department of Environmental Quality Engineering, under the Nationwide Urban Runoff Program (NURP) evaluated the impact of the specific water pollution problem of urban runoff as it affects Lake Quinsigamond and its tributaries. The purposes of this program are to evaluate alternative runoff control methods and their effectiveness and recommend a program for the control of urban runoff throughout the watershed.

This report summarizes the data analyzed by the programs described above and presents a recommended series of controls designed to correct or eliminate sources of water pollution throughout the watershed. These recommended actions are collectively referred to as a watershed management plan for the Lake Quinsigamond drainage areas. If fully implemented, this plan should result in the achievement of water quality goals and objectives such that the region's populace can continue to enjoy Lake Quinsigamond, Flint Pond and their surrounding environs for land and water-based recreation and to use the lake as a source of clean drinking water.

The comparison of Lake Quinsigamond and other lakes within an 80 kilometer radius presents Lake Quinsigamond as a diverse recreational resource which is extensively utilized. The total list of usages to which lakes within an 80 kilometer radius are put includes industrial water, drinking water, fishing, ice skating, motor boating, non-motorized boating, and swimming.

B. DESCRIPTION OF THE LAKE QUINSIGAMOND DRAINAGE BASIN

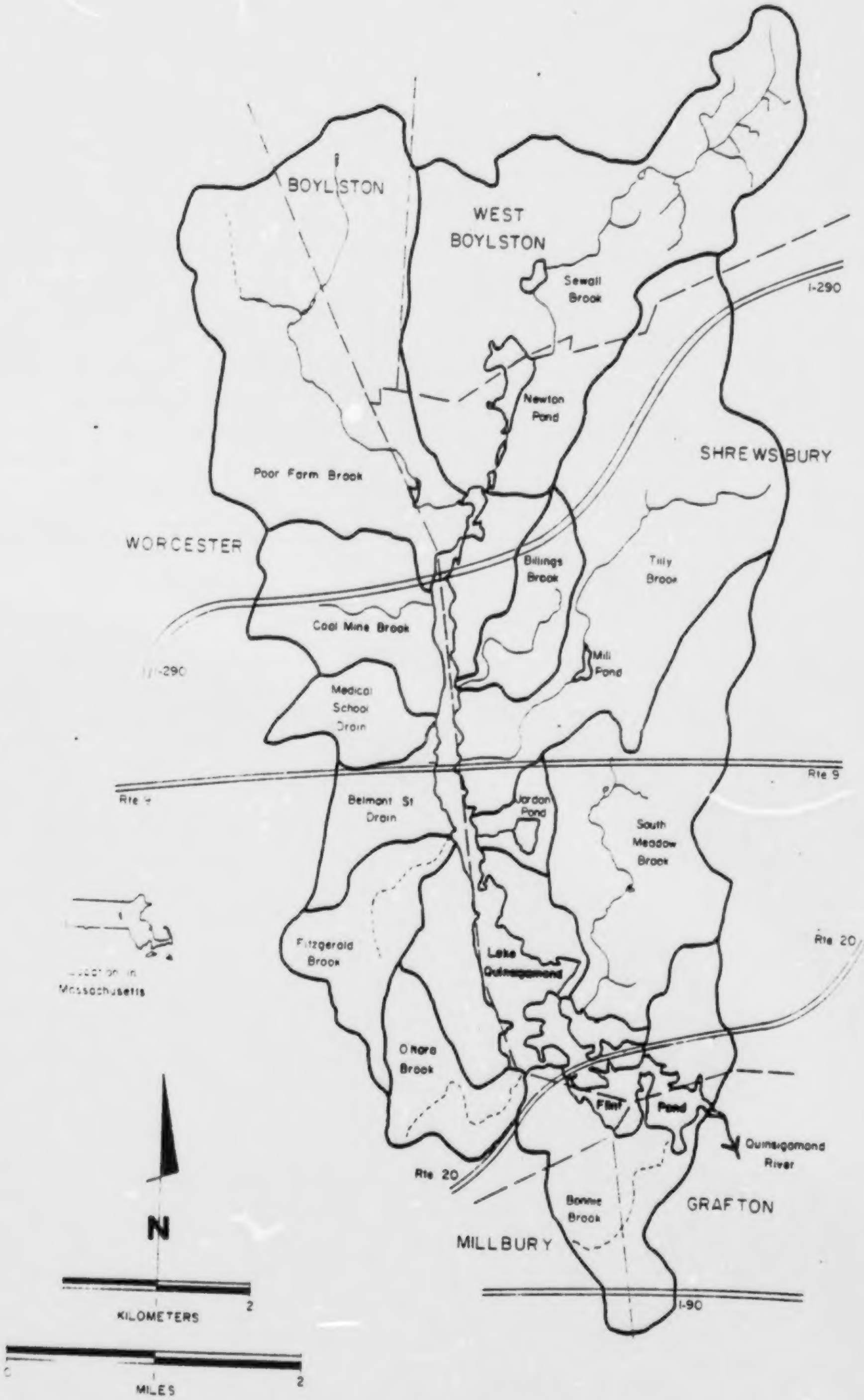
Lake Quinsigamond drainage basin is a headwater basin of the Blackstone River, rising immediately to the east of that river's origin. The Quinsigamond River is the lake's outlet, and flows to its juncture with the Blackstone at Fisherville Pond in the Town of Grafton, Massachusetts. The Blackstone River then carries the combined flows southeast into Rhode Island and the Seekonk River, which is tidal and flows into the Providence River and thence into Narragansett Bay.

As depicted in Figure I-1, Lake Quinsigamond is separated into two distinct sections: the deep narrow northern basin and the shallow southern basin known as Flint Pond. The total area of the lake is 772 acres comprised of 475 acres in the northern basin and 297 acres in Flint Pond. The Lake Quinsigamond Drainage Basin occupies a total area of about 25 square miles (16,000 acres). The lake has a maximum depth of 92 feet and an average depth of 20.7 feet. The lake is approximately five miles long, with the width varying from 250 feet to nearly a mile. The lake volume is estimated at 688 million cubic feet at MSL elevation 358 feet.

The single outlet of the lake is located at Irish Dam with the outflow creating the Quinsigamond River. The major inlet to the lake is from a series of ponds north of the main body of the lake. Approximately 16 small tributaries also feed the lake. These tributaries drain sub-basins varying in size from less than one square mile to over 5 square miles. Figure I-1 shows Lake Quinsigamond is located in the heart of Worcester County, Massachusetts and lies between the City of Worcester and the Town of Shrewsbury. The lake's drainage basin encompasses portions of Worcester, Shrewsbury, Boylston, and West Boylston, plus corners of Grafton and Millbury.

Worcester and Shrewsbury, which occupy the majority of the Lake Quinsigamond Basin, are the two most populous of the municipalities in the drainage basin. In terms of generalized economic and demographic trends, Shrewsbury (located on the east shore of Lake Quinsigamond), is characterized as an area of moderate

LAKE QUINSIGAMOND & FLINT POND


BOYLSTON
WEST BOYLSTON
Sewall Brook
I-290
Newton Pond
SHREWSBURY
Poor Farm Brook
WORCESTER
Billings Brook
Tilly Brook
Coal Mine Brook
Mill Pond
I-290
Medical School Drain
Rte 9
Rte 9
Belmont St Drain
Jordan Pond
South Meadow Brook
Rte 20
Fitzgerald Brook
Lake Quinsigamond
Location in Massachusetts
Ohara Brook
Flint Pond
Quinsigamond River
Rte 20
Bonnie Brook
GRAFTON
N
MILLBURY
I-90
KILOMETERS
2
0
MILES
2

FIGUBE I-1

=

to high population growth but slow industrial/commercial expansion. Worcester, Grafton and Millbury are characterized as areas of slight decline or very slow population and industrial/commercial growth.

Lake Quinsigamond lies in a north-south direction and is crossed by three major highways: Interstate I-290, State Route 9 and U.S. Route 20. Being situated in a highly urban area, the lake supports multiple recreational uses including fishing, boating, water-skiing and bathing. The entire periphery of the lake is densely settled with many private homes and some commercial establishments. Two state parks, several private beaches and marinas are located along the shorefront. The central part of the drainage basin in the vicinity of Route 9 is highly developed and much of the land area is covered with buildings, roads, and parking lots. A large portion of the land area of one of the sub-basins has been stripped for sand and gravel purposes. Considerable construction is occurring or is planned in the basin as a whole.

Lake Quinsigamond lies in an area known for its climatological extremes. Severe weather of one form or another generally occurs in the area each year. These forms include extreme hot or cold, heavy rain, drought, snow or ice and damaging thunderstorms. A tornado or hurricane is also experienced from time to time. On the average, however, temperatures are moderate and precipitation is quite evenly distributed throughout the year. The Worcester weather station reports a mean annual precipitation of 46.20 inches and mean annual temperature of 47.0 ° F.

Lake Morphometry

The Lake Quinsigamond drainage basin is an area of strong topological variation. Elevations generally increase to the north and west, ranging from 355 feet at Flint Pond to well over 700 feet at steep hills that dot the upland divide on all sides of the basin.

Morphological characteristics of the lake are depicted on the bathymetric map presented in Figure I-2. Lake Quinsigamond proper slopes abruptly from the shoreline to depths of 40 to 90 feet. Such depths are found over much of the lake. The maximum depth occurs below the inflow from Coal Mine Brook. Depths of 5 to 15 feet predominate in the much shallower Flint Pond. Figure I-3 shows the relationship between surface area, volume and depth. The graphic shows the steep gradients in the deep part of the lake and the shallow slopes near the shorelines.

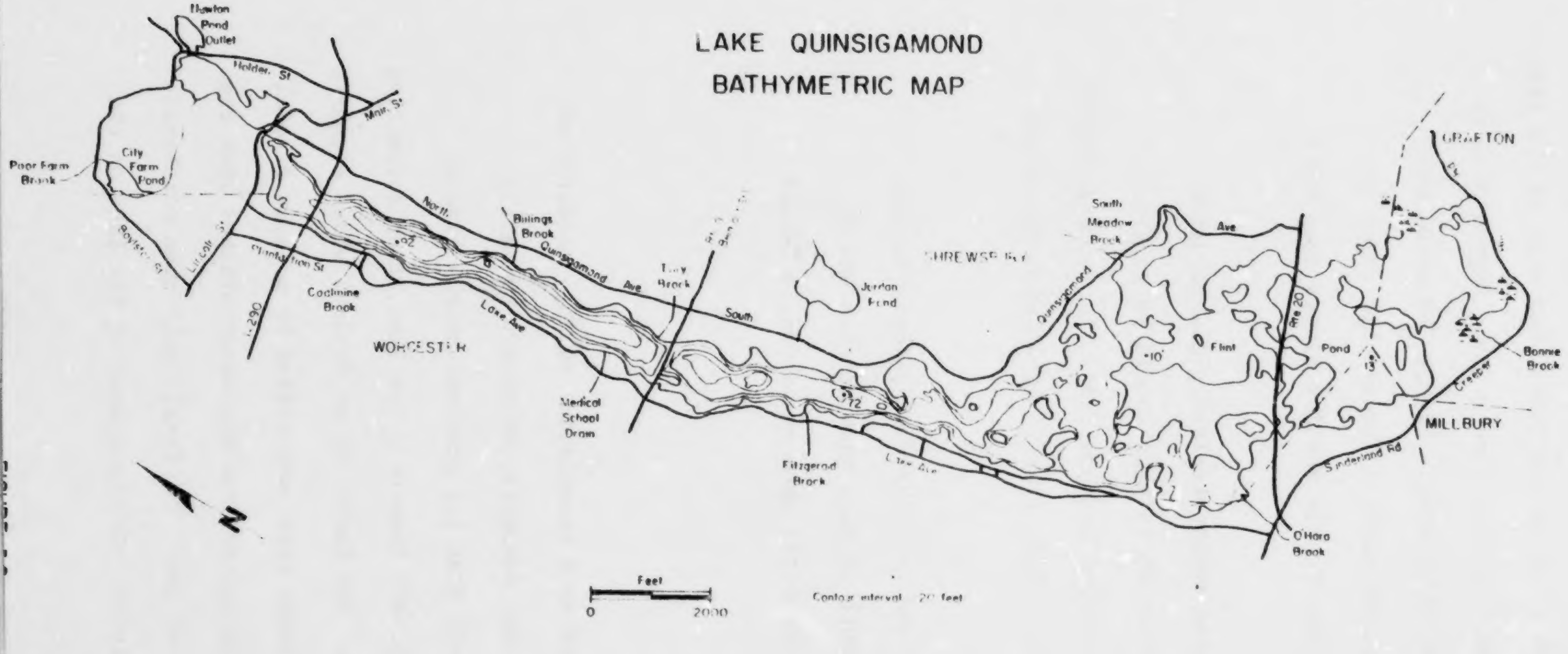
Lake Quinsigamond can be considered morphometrically as two water bodies: Lake Quinsigamond and Flint Pond (which in turn should be considered as a north and south pond). The lake is stratified and classified as mesotrophic (Massachusetts Lake Classification Program, DWPC, 1977). Detailed morphometric data are shown in Table I-1.

Flint Pond north is unstratified and is classified as oligotrophic tending toward mesotrophic; Flint Pond south is also unstratified and is classified as mesotrophic. Detailed morphometric data are shown in Tables I-2 and I-3, respectively.

Geology and Hydrology

Lake Quinsigamond can be described as a pre-glacial valley, bordered on the north, east and south by glacial outwash deposits, which are primarily comprised of sand and gravel. It is likely that the area was once a glacial sluice extending from the area where Wachusett Reservoir now lies, thus accounting for the large amounts of glacial outwash. The Nashua River Valley, whose southern extreme is occupied by the Wachusett drainage area, was filled by a large glacial lake that spilled southward through the Worcester area and later drained when the north-running Nashua Valley became clear of ice. The Sewall Hill area northeast of the lake is glacial till on top of bedrock. The area west of the lake on the

LAKE QUINSIGAMOND
BATHYMETRIC MAP


Newton Pond Outlet
Holden St
Main St
Poor Farm Brook
City Farm Pond
Boylston St
Lincoln St
Plantation St
I-290
Coolidge Brook
WORCESTER
North
Billings Brook
Quinsigamond Ave
Lake Ave
Medical School Drain
Tory Brook
South
Jordan Pond
SHREWSBURY
Fitzgerald Brook
Lake Ave
South Meadow Brook
Quinsigamond
Ave
Flint
Rte 20
Pond
Sunderland Rd
O'Hara Brook
GRAFTON
Bonnie Brook
Creeper
MILLBURY
N
Feet
0
2000
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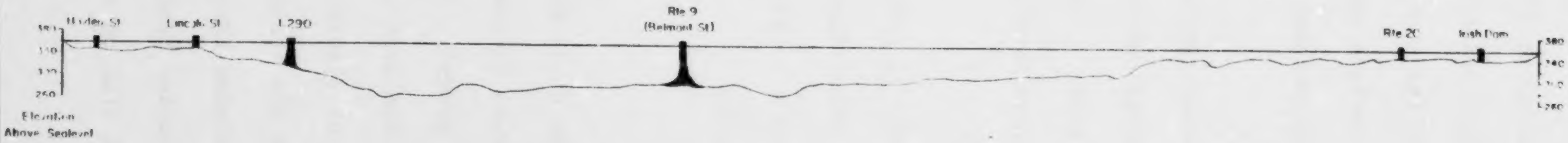
DEPTH PROFILE



LAKE QUINSIGAMOND
SURFACE AREA, VOLUME and DEPTH RELATIONSHIPS*

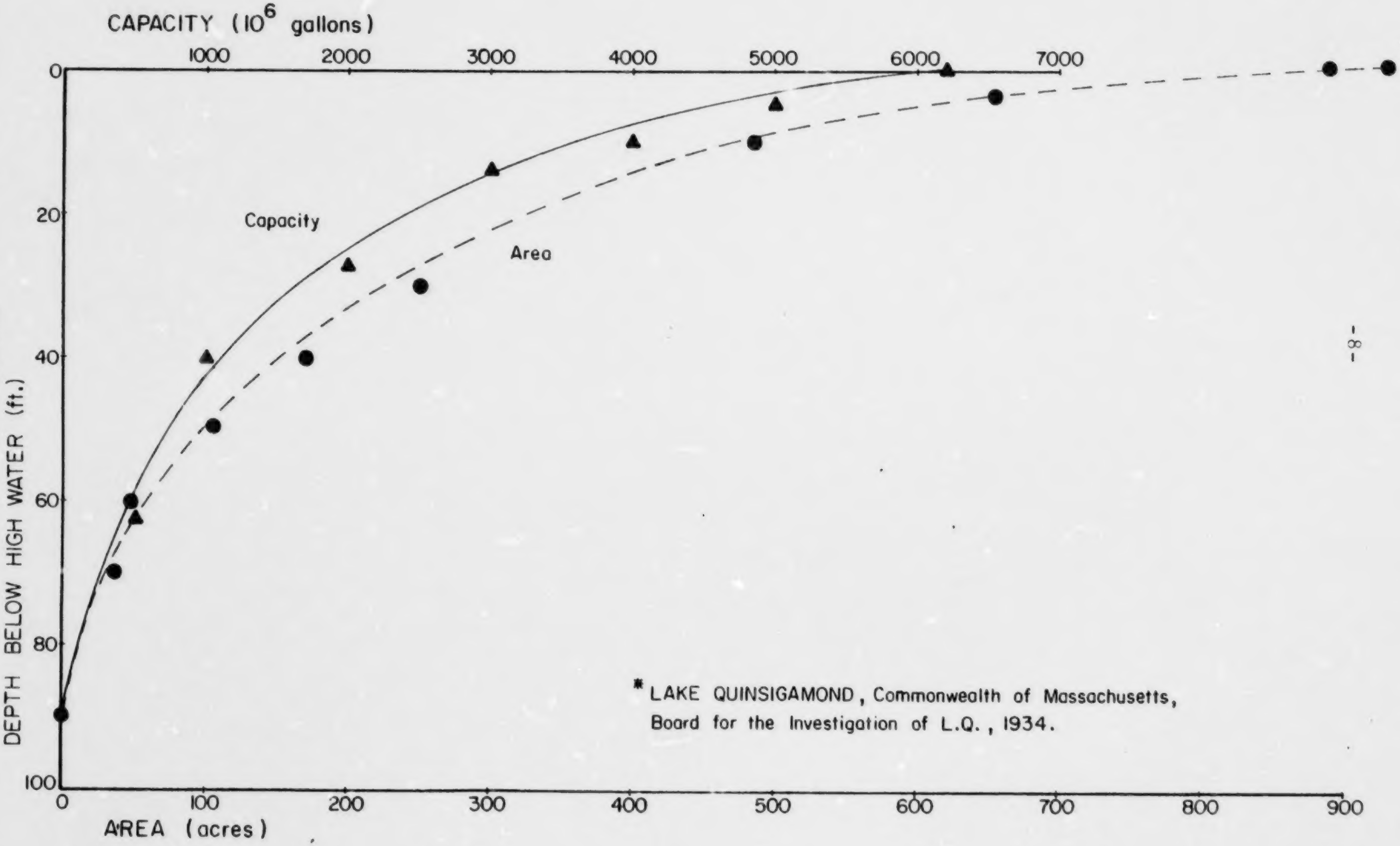


FIGURE I-3

* LAKE QUINSIGAMOND, Commonwealth of Massachusetts, Board for the Investigation of L.Q., 1934.

TABLE I-1

LAKE QUINSIGAMOND

MORPHOMETRIC DATA

Maximum Length	5 miles (8 kilometers)
Maximum Effective Length	2.27 miles (3.63 kilometers)
Maximum Width	3,800 feet (1,155 meters)
Maximum Effective Width	3,800 feet (1,155 meters)
Maximum Depth	85 feet (25.8 meters)
Mean Depth	33 feet (10.0 meters)
Mean Width	784 feet (238 meters)
Area	475 acres (192 hectares)
Volume	15,611 acre feet (19,040,424 cu. meters)
Shoreline	56,000 feet (17,024 meters)
Development of Shoreline	3.47
Development of Volume	1.16
Mean to Maximum Depth Ratio	0.38
Drainage Area	20.84 sq. miles (53.95 sq. kilometers)

TABLE I-2

FLINT POND NORTH

MORPHOMETRIC DATA

Maximum Length	3,450 feet (1,049 meters)
Maximum Effective Length	2,300 feet (699 meters)
Maximum Width	2,150 feet (653 meters)
Maximum Effective Width	1,350 feet (410 meters)
Maximum Depth	12 feet (3.6 meters)
Mean Depth	9 feet (2.7 meters) (entire pond)
Mean Width	1,061 feet (323 meters)
Area	84 acres (33.9 hectares)
Volume	2,325 acre feet (2,835,756 cu. meters) (entire pond)
Shoreline	12,000 feet (3,648 meters)
Development of Shoreline	1.77
Development of Volume	1.80 (entire pond)
Mean to Maximum Depth Ratio	0.60 (entire pond)
Drainage Area	2.38 sq. miles (6.16 sq. kilometers)

TABLE I-3

FLINT POND SOUTH

MORPHOMETRIC DATA

Maximum Length	4,900 feet (1,489 meters)
Maximum Effective Length	3,200 feet (973 meters)
Maximum Width	2,900 feet (881 meters)
Maximum Effective Width	2,900 feet (881 meters)
Maximum Depth	15 feet (4.5 meters)
Mean Depth	9 feet (2.7 meters) (entire pond)
Mean Width	1,511 feet (459 meters)
Area	170 acres (68.7 hectares)
Volume	2,325 acre feet (2,835,756 cu. meters) (entire pond)
Shoreline	25,000 feet (7,600 meters)
Development of Shoreline	2.59
Development of Volume	1.80 (entire pond)
Mean to Maximum Depth Ratio	0.60 (entire pond)
Drainage Area	0.98 sq. miles (2.53 sq. kilometers)

Worcester shore is predominately bedrock.

A permanent USGS* stream gaging station, located one mile downstream of the Irish Dam outlet of Lake Quinsigamond, provides a continuous flow record (digital water-stage recorder and rating curve) of the Quinsigamond River.

Monthly flow data from the USGS gauge on the Quinsigamond River below the lake (station 01110000) have been compiled and analyzed for water years 1968-79. This information provides a basis for assessing possible impacts of hydrologic variations on water quality and has been used in lake modelling efforts. Mean monthly flows are tabulated in Table I-4 and displayed in Figure I-4. A data summary by water year is given in Figure I-5. In Figure I-6, the average hydraulic residence time is estimated by integrating backwards in the time series of mean monthly flows until one lake volume (688 million cubic feet) is reached. Seasonal flow variations generally cause residence times to vary between 0.4 and 1 year during any water year. Table I-5 summarizes important hydrologic variables for dry, average, and wet years, based upon 12 water years of record. On the average, Lake Quinsigamond and Flint Pond have a residence time of 0.5 years and a surface overflow rate of 12.4.meters/year.

Comparisons of hydrologic conditions during 1971 and 1979 provide a partial basis for interpreting and comparing water quality data available for these years. Water year 1971 was relatively dry (30.3 cfs) compared with 1979 (46.3 cfs). Perhaps of greater significance is the seasonal distribution of runoff in these two years. In 1971, the maximum monthly flow of 89.3 cfs occurred in March. In 1979, the maximum flow of 159 cfs occurred during January, the result of a mid-winter thaw. This was the maximum monthly flow recorded in the 12-year period. These differences may have had a major impact on water quality variations in these water years. The lake stratified about a month earlier in 1979 compared with 1971. This may be attributed in part to differences in the timing and magnitude of peak runoff, as well as to other climatologic variables.

* USGS - United States Geological Survey

TABLE I-4

Quinsigamond River
MEAN MONTHLY FLOWS (cfs)
USGS 01110000

YEAR	MONTH	FLOW
67	10	14.80
67	11	16.00
67	12	37.10
68	1	31.30
68	2	41.20
68	3	132.00
68	4	55.40
68	5	37.70
68	6	61.70
68	7	42.60
68	8	11.40
68	9	8.16
68	10	7.81
68	11	27.50
68	12	45.80
69	1	31.90
69	2	38.10
69	3	84.30
69	4	98.40
69	5	46.00
69	6	16.40
69	7	10.60
69	8	13.90
69	9	17.50
69	10	8.50
69	11	39.90
69	12	67.70
70	1	45.90
70	2	141.00
70	3	58.10
70	4	103.00
70	5	40.90
70	6	27.80
70	7	8.61
70	8	8.54
70	9	5.27
70	10	9.79
70	11	20.40
70	12	23.60
71	1	18.10
71	2	41.30
71	3	89.30
71	4	61.30
71	5	56.00
71	6	13.70
71	7	10.90
71	8	6.91
71	9	12.50
71	10	14.10
71	11	15.10
71	12	42.80
72	1	45.70
72	2	62.70
72	3	154.00
72	4	84.50
72	5	89.00
72	6	99.20
72	7	44.20
72	8	14.30
72	9	16.60
72	10	26.10
72	11	80.70
72	12	93.50
73	1	78.40
73	2	84.00
73	3	63.20
73	4	80.80
73	5	56.00
73	6	40.00
73	7	43.90
73	8	23.30
73	9	14.10
73	10	8.06
73	11	18.30
73	12	74.70
74	1	66.10
74	2	66.60
74	3	77.80
74	4	88.40
74	5	50.10
74	6	29.80
74	7	15.30
74	8	2.28
74	9	30.50
74	10	38.90
74	11	29.80
74	12	56.60
75	1	65.60
75	2	61.50
75	3	70.00
75	4	55.40
75	5	31.10
75	6	23.90
75	7	6.92
75	8	7.26
75	9	19.30
75	10	53.30
75	11	65.90
75	12	57.00
76	1	75.10
76	2	88.30
76	3	60.80
76	4	44.80
76	5	41.50
76	6	12.00
76	7	6.57
76	8	18.90
76	9	4.40
76	10	14.10
76	11	9.19
76	12	14.30
77	1	10.30
77	2	11.00
77	3	97.30
77	4	80.90
77	5	60.10
77	6	23.70
77	7	13.60
77	8	7.48
77	9	14.50
77	10	46.70
77	11	49.30
77	12	70.40
78	1	102.00
78	2	56.60
78	3	72.60
78	4	79.00
78	5	50.10
78	6	22.80
78	7	10.10
78	8	18.10
78	9	3.00
78	10	9.92
78	11	5.48
78	12	20.50
79	1	159.00
79	2	38.10
79	3	84.80
79	4	60.40
79	5	52.80
79	6	34.00
79	7	24.60
79	8	33.60
79	9	32.50

FIGURE I-4 MEAN MONTHLY FLOWS - Quinsigamond River

(Hydrologic Water Year: October-September)

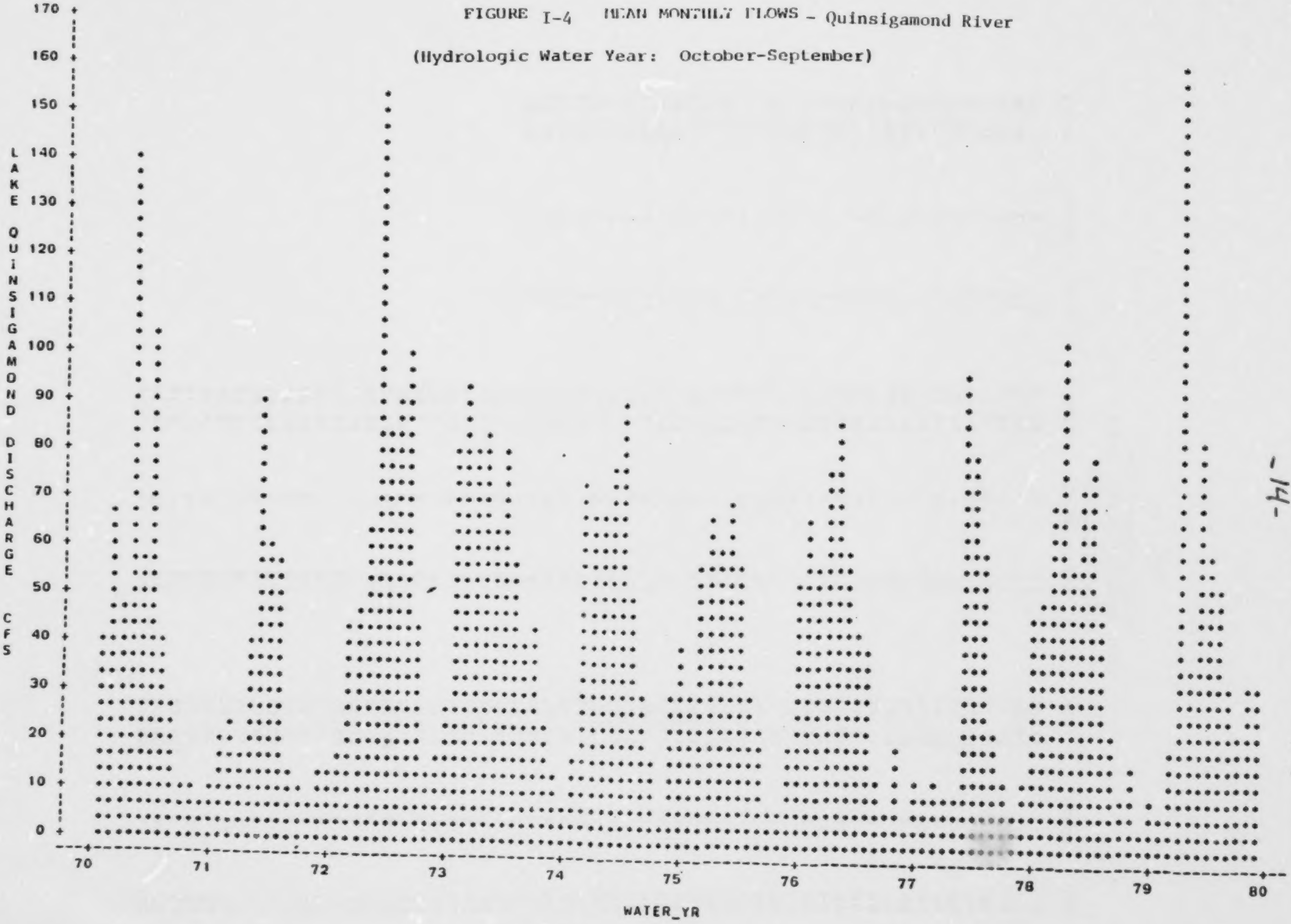
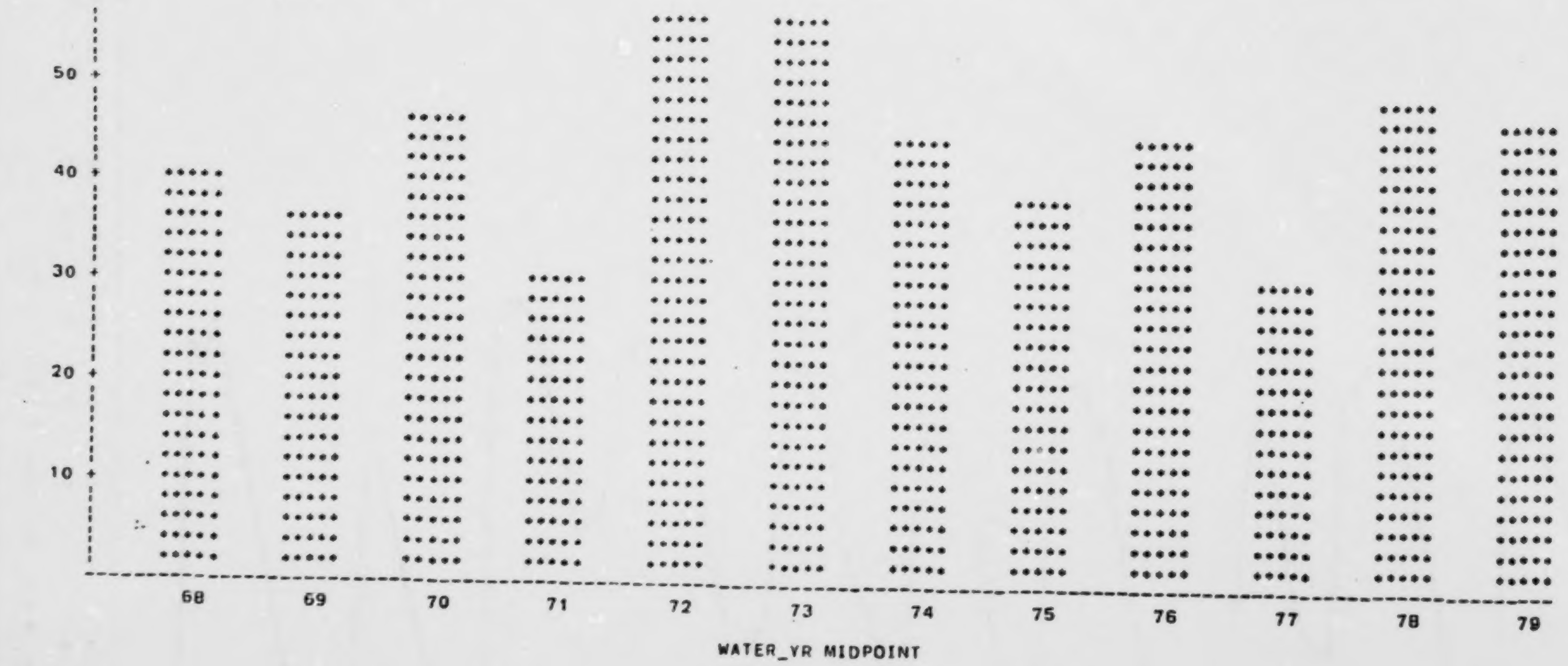


FIGURE I-5 MEAN WATER-YEAR FLOWS (cfs)

Quinsigamond River



Statistical Summary

WATER_YR	MEAN	STD	MIN	MAX
68	40.7800	33.4462	8.16	132.0
69	36.5175	28.8690	7.81	98.4
70	46.2683	41.7257	5.27	141.0
71	30.3167	26.0275	6.91	89.3
72	56.8500	43.2193	14.10	154.0
73	57.0000	27.0996	14.10	93.5
74	43.9950	30.1405	2.28	88.4
75	38.8567	22.4682	6.92	70.0
76	44.0475	27.9237	4.40	88.3
77	29.7058	31.2796	7.48	97.3
78	48.3917	30.2329	3.00	102.0
79	46.3083	41.6928	5.48	159.0

FIGURE 7-6

AVERAGE HYDRAULIC RESIDENCE TIME OF LAKE QUINSIGAMOND

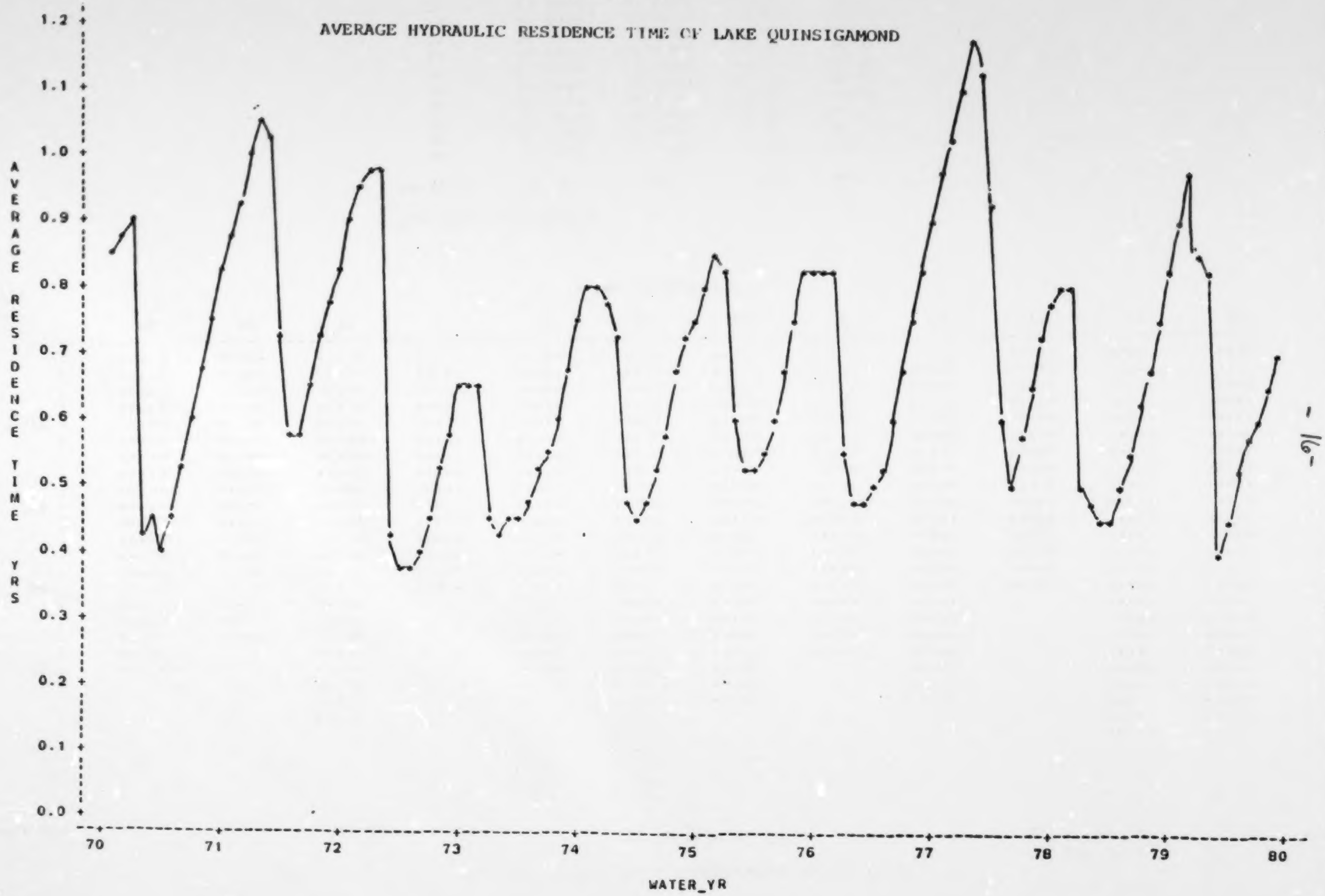


TABLE I-5

LAKE QUINSIGAMOND HYDROLOGY SUMMARY

Variable	Water Year* Dry	Average	Wet
Discharge (cfs)	29.7	43.3	57.0
Hydraulic Residence Time (yr)	0.73	0.50	0.38
Surface Overflow Rate (m/yr)	8.5	12.4	16.3

*Key: Based on minimum, mean, and maximum annual flow, water years 1968-1979.

II Water Quality Conditions

A. Introduction

The assessment of water quality conditions in any water body can be undertaken with varying degrees of complexity and levels of analysis. These range from the perception of a problem (i.e. "I've lived here a number of years and conditions are either worse, better or can't tell") to extensive field and laboratory investigations spanning years of data collection and analysis. Although statements of perceived problems are important in terms of identifying problems, the latter approach is required where decisions must be made to allocate financial and/or other resources in order to correct identified water quality problems. In order to assess the water quality conditions of Lake Quinsigamond, Flint Pond and their respective tributaries, an extensive sampling program was undertaken. The purposes of this section are to describe the various elements of the sampling program, discuss the results of the sampling program and to present conclusions regarding the water quality conditions of this system, and to suggest water quality objectives appropriate to the desired uses of these water bodies.

B. Sampling Programs

Prior to 1980, major sampling programs had been conducted on the Lake Quinsigamond/Flint Pond watershed in 1971 (Mass, DWPC),1975 (Central Mass. Reg. Planning Commission 208 Program) and again in 1979 by the Division of Water Pollution Control. Also, between 1972 and the present time, bacterial monitoring of major bathing and other recreational areas, tributaries and other areas has been conducted by the health departments of the communities of Worcester and Shrewsbury.

In order to supplement the existing data base and to more clearly define cause-effect relationships between storm events and in-lake water quality impacts on both a short and long-term basis, an expanded sampling program for the lake and its tributaries was jointly developed by the DWPC 314 staff and the DEQE-NURP staff. A multi-component sampling program was designed to address the program data objectives of both the 314 diagnostic and NURP programs. The major components of the sampling program included monitoring of in-lake and natural tributaries, upper watershed tributary monitoring, sediment sampling of lake stations and tributaries, and stormwater sampling. Flow gaging was conducted on major tributaries and stage/discharge rating curves were developed for each. Supplemental data collection programs included a fisheries survey conducted jointly by the NURP staff and the Massachusetts Division of Fisheries & Wildlife and algal assay studies conducted cooperatively between the NURP staff, and the DWPC Research and Demonstration project with the University of Massachusetts Department of Civil Engineering. The following sections describe the major components of the in-lake, tributary and sediment sampling programs. Stormwater sampling is discussed in a subsequent chapter of this report. Other sampling activities referenced above are further detailed in the discussion of results later in this chapter.

1. In-Lake & tributary sampling program(314 sampling)

A total of twenty seven sampling stations were sampled on a bi-weekly basis from April through November of 1980 under this program. Eighteen stations were located on Lake Quinsigamond and its tributaries and nine were located on Flint Pond and its tributaries. Table II-1 lists all of these stations. The stations are shown on Figure II-1. Water quality samples were analyzed for the following parameters:

Temperature
Dissolved Oxygen
pH
Total Solids
Suspended Solids
Total Kjeldahl Nitrogen
Ammonia-Nitrogen
Nitrate-Nitrogen
Total Phosphorus
Dissolved Phosphorus
Total Hardness
Chloride
Total Alkalinity
Conductivity (Specific Conductance)
Sulfate
Iron
Manganese
Silica
Color
Total Coliform Bacteria
Fecal Coliform Bacteria
Fecal Streptococcus Bacteria

TABLE II-1

LAKE QUINSIGAMOND

SAMPLING STATIONS

Lake Quinsigamond

Q01 - Lake - 90 feet (27.3 meters) Max. Depth
Q02 - Lake - 60 feet (18.2 meters) Max. Depth
Q03 - Lake - 80 feet (24.2 meters) Max. Depth
Q04 - Lake - 50 feet (15.2 meters) Max. Depth
Q05 - Lake - Surface @ 290 Bridge
Q06 - Lake - Surface @ Route 9 Bridge
Q08 - Fitzgerald Brook
Q09 - Coal Mine Brook
Q10 - Poor Farm Brook
Q11 - Newton Pond Outlet
Q12 - Lake @ Lincoln Street
Q13 - Billings Brook
Q15 - O'Hara Brook
Q16 - Medical School Drain
Q17 - Tilly Brook
Q18 - Jordan Pond Outlet
Q19 - Belmont Street Drain
Q20 - Channel below Belmont Street Drain

Flint Pond

F01 - Pond - 9.9 feet (3 meters), 3.3 feet (1.5 meters)
F02 - Pond at Surface
F03 - Pond - 13.2 feet (4 meters), 6.6 feet (2 meters)
F04 - Pond at Surface
F05 - Pond at Surface
F06 - South Meadow Brook
F07 - Inlet from Lake Quinsigamond
F08 - Outlet of Pond at Irish Dam
F09 - Bonnie Brook

LAKE QUINSIGAMOND / FLINT POND
314 LAKE & TRIBUTARY SAMPLING STATIONS

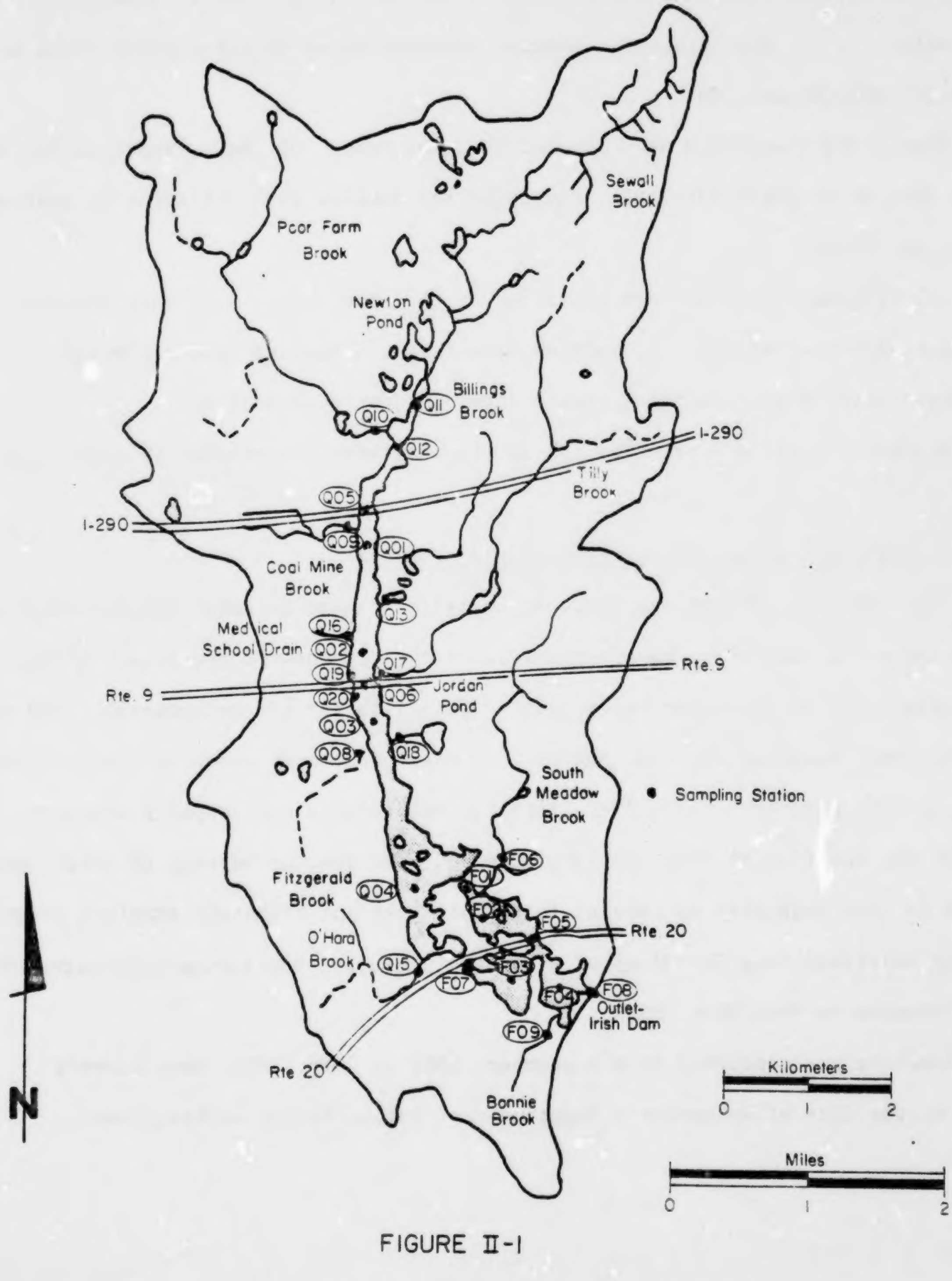

Sewall Brook
Poor Farm Brook
Newton Pond
Billings Brook
Q10
Q11
Q12
I-290
I-290
Tilly Brook
Q05
Q09
Q01
Coal Mine Brook
Q13
Medical School Drain
Q16
Q02
Q19
Q17
Rte. 9
Rte. 9
Q20
Q06
Jordan Pond
Q03
Q08
Q18
South Meadow Brook
Sampling Station
F06
F01
Fitzgerald Brook
Q04
F02
F05
Rte 20
O'Hara Brook
Q15
F03
F07
F04
F08
Outlet-Irish Dam
F09
Rte 20
Bonnie Brook
N
Kilometers
0
1
2
Miles
0
1
2

FIGURE II-1

Of the eighteen sampling stations on Lake Quinsigamond, eight were in-lake stations. The remaining ten stations consisted of the major tributaries and the outfall below the Belmont Street Drain. Stations Q01,Q02, Q03, and Q04 were sampled at ten foot depth intervals for temperature and dissolved oxygen. Chemical samples at these stations were collected at the surface, thermocline, fifty foot and bottom intervals. Remaining in-lake stations, including stations Q05,Q06,Q12 and Q20 were sampled at the surface only. Phytoplankton samples were collected at the surface level at stations Q01,Q02,Q03 and Q04.

Five in-lake stations were located in Flint Pond. Of these, stations F01 and F03 were sampled at depth intervals. Phytoplankton samples were collected at stations F01, F03, and F04.

All tributary samples were collected at the same location on each sampling date. Staff gages were read at the time samples were taken. Readings were converted to flow measurements using stage/discharge curves developed for each station.

All water quality data collected during this sampling program is summarized in Appendix I.

2. Upper Watershed Tributary Monitoring Program

This sampling program was designed to define trends in water quality related to land use and other watershed characteristics; to identify new or previously undetected problem areas; and to establish water quality baselines for the tributaries. Six major tributaries were selected for this purpose. A total of twenty sampling stations were included in this program. Table II-2 lists the tributaries and sampling stations. Figure II-2 shows the location of each sampling station. One station on each tributary duplicated a station on that tributary as sampled in the 314 lake and tributary sampling program previously described.(e.g.Sta #1,upper watershed Tributary Monitoring duplicates Q10,314 sampling program on Poor Farm Brook).

Sampling was conducted from September, 1980 to July, 1981. Samples were analyzed at the City of Worcester's Department of Public Health laboratories.

TABLE II-2

LAKE QUINSIGAMOND NURP PROJECT

UPPER WATERSHED TRIBUTARY MONITORING

SAMPLING STATIONS

Poor Farm Brook

STA #1 : at staff gage behind Shrewsbury Industrial Park (Shrewsbury)
STA #2 : at Route 70 Bridge (Shrewsbury)
STA #3 : at staff gage below Clark Street(Worcester)
STA #4 : at East Mountain Street, below golf course (Worcester)
STA #5 : at Hospital Drive(West Boylston)

Coal Mine Brook

STA #6 : at Lake Avenue at gage (Worcester)
STA #7 : at Plantation Street (Worcester)
STA #8 : below culvert at Notre Dame convent entrance (Worcester)
STA #9 : confluence with I-290/Lincoln Plaza drain - Notre Dame property (Worcester)
STA #10: at culvert below I-290 (Worcester)

Fitzgerald Brook

STA #11: at staff gage on Lake Avenue (Worcester)
STA #12: below Coburn Avenue (Worcester)

O'Hara Brook

STA #13: at staff gage on culvert behind 17 Whitla Drive (Worcester)

Tilly Brook

STA #14: West Brook at Main Street (Shrewsbury)
STA #15: Outlet of Mill Pond (Shrewsbury)
STA #16: at culvert above Spag's parking lot (Shrewsbury)
STA #17: at staff gage on Harvey Place drain (Shrewsbury)

South Meadow Brook

STA #18: at Route 9 (Shrewsbury)
STA #19: at Oak Street between Dalphen Rd. and Judick St. (Shrewsbury)
STA #20: at staff gage at South Quinsigamond Avenue (Shrewsbury)

LAKE QUINSIGAMOND
UPPER WATERSHED TRIBUTARY MONITORING STATIONS

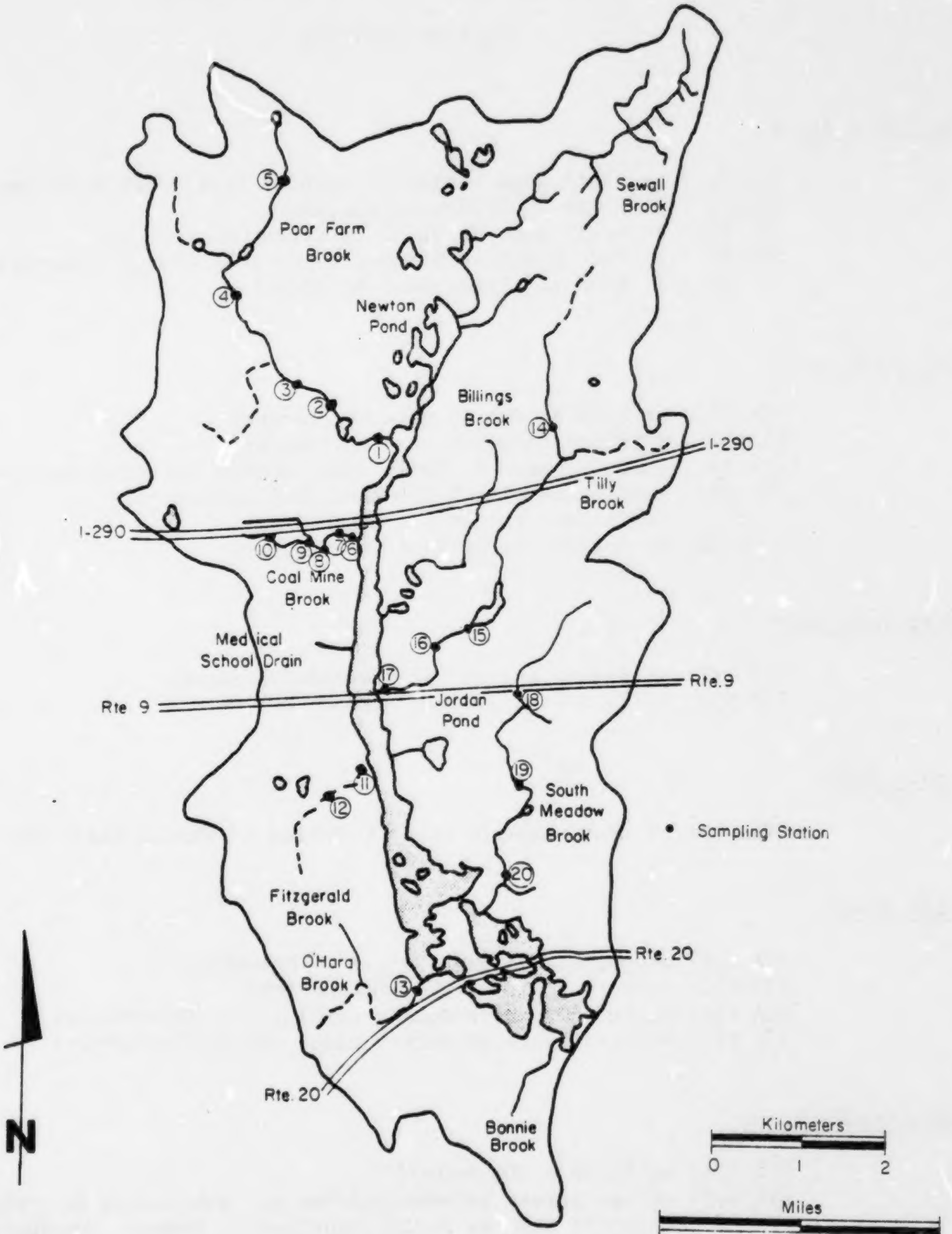

Poor Farm Brook
Newton Pond
Sewall Brook
Billings Brook
Tilly Brook
I-290
I-290
Coal Mine Brook
Medical School Drain
Rte 9
Rte. 9
Jordan Pond
South Meadow Brook
Fitzgerald Brook
O'Hara Brook
Rte. 20
Rte. 20
Bonnie Brook
• Sampling Station
N
Kilometers
0
1
2
Miles
0
1
2
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

FIGURE II-2

Parameters included the following:

pH
Dissolved Oxygen
Temperature
Total Solids
Total Hardness
Chloride
Conductivity
Total Kjeldahl Nitrogen
Ammonia-Nitrogen
Nitrate-Nitrogen
Nitrite-Nitrogen
Total Phosphorus
Total Alkalinity
Total and Fecal Coliform Bacteria
Fecal Streptococcus Bacteria

Data from this program is incorporated in the discussion of each tributary in section C of this chapter.

3. Sediment Sampling Program

Sediment samples were collected at twenty four stations in Lake Quinsigamond, Flint Pond and small selected tributaries to determine nutrient and heavy metals content. Chemical analysis included arsenic, cadmium, chromium, copper, lead, nickel, zinc, total nitrogen, total phosphorus and percent volatile solids. Sampling stations are shown in Figure II-3. The data collected from this sampling activity is incorporated in the discussion of results in a following section of this chapter.

4. Stormwater Sampling Program

A major stormwater program, sponsored by the EPA Nationwide Urban Runoff Program, was conducted at six locations in the Lake Quinsigamond Watershed. Figure II-4 shows the location of these sampling stations. This sampling program and its results are presented in a separate section of the report. Priority Pollutant* sampling was conducted at stations P2 and P3 under a special grant to the NURP project from the EPA Office of Water Regulations and Standards Monitoring and Data Support Division.

5. Quality Assurance

In order to ensure the consistency, reliability and validity of the scientific and technical data base upon which decisions must be based, a quality assurance plan was adopted prior to the initiation of the sampling programs

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* Priority Pollutants defined by EPA Regulations - includes 129 parameters

LAKE QUINSIGAMOND
SEDIMENT SAMPLING STATIONS

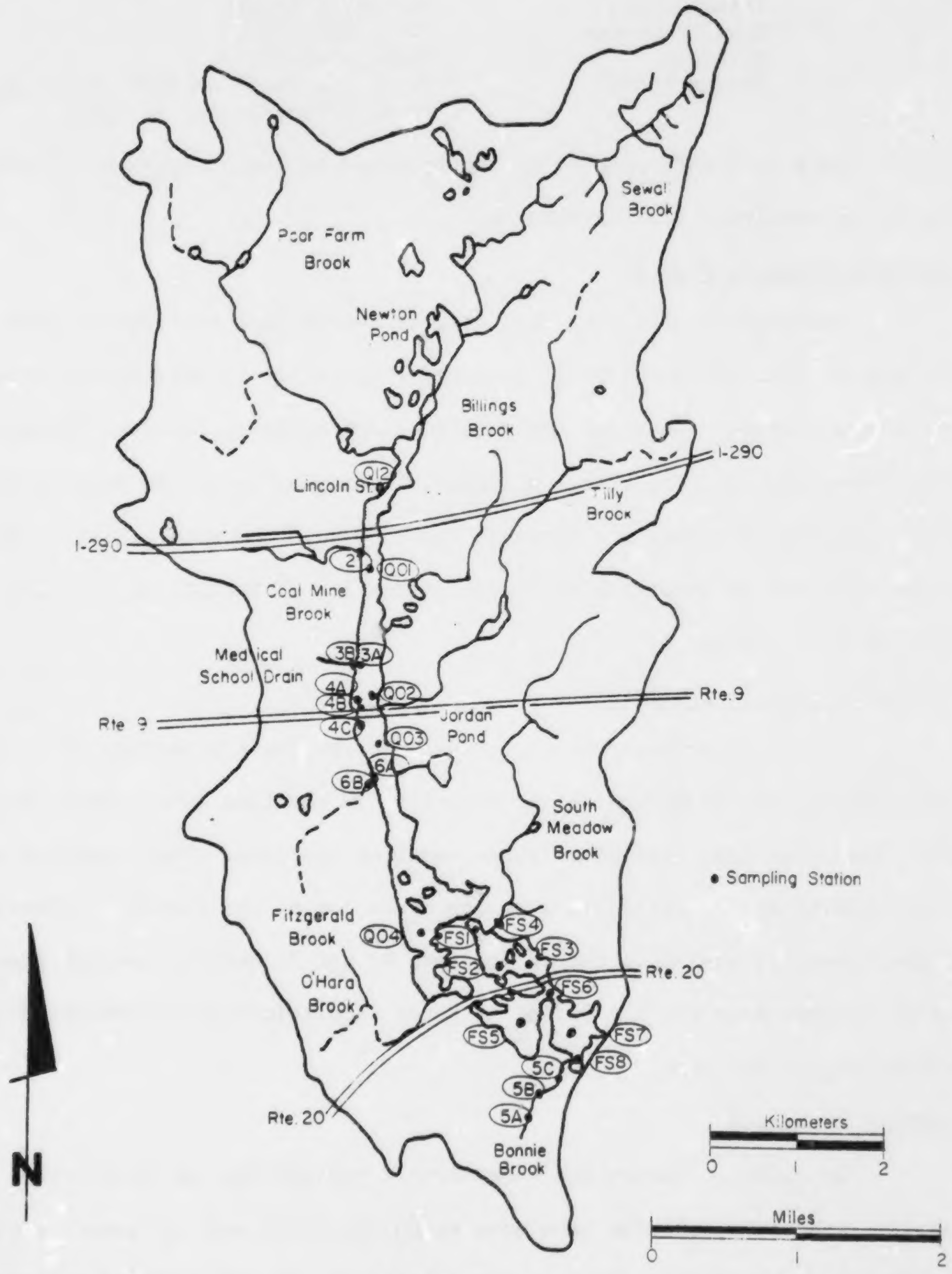

Poor Farm Brook
Sewall Brook
Newton Pond
Billings Brook
I-290
Q12
Lincoln St.
Tilly Brook
I-290
2
Q01
Coal Mine Brook
Medical School Drain
3B
3A
4A
4B
4C
Q02
Rte. 9
Rte 9
Jordan Pond
Q03
6A
6B
South Meadow Brook
• Sampling Station
Fitzgerald Brook
Q04
FS1
FS2
FS3
FS4
FS5
FS6
FS7
FS8
Rte. 20
O'Hara Brook
Rte. 20
5C
5B
5A
Bonnie Brook
Kilometers
0
1
2
Miles
0
1
2
N

FIGURE II-3

LAKE QUINSIGAMOND
NURP PRIMARY STORMWATER SAMPLING STATIONS

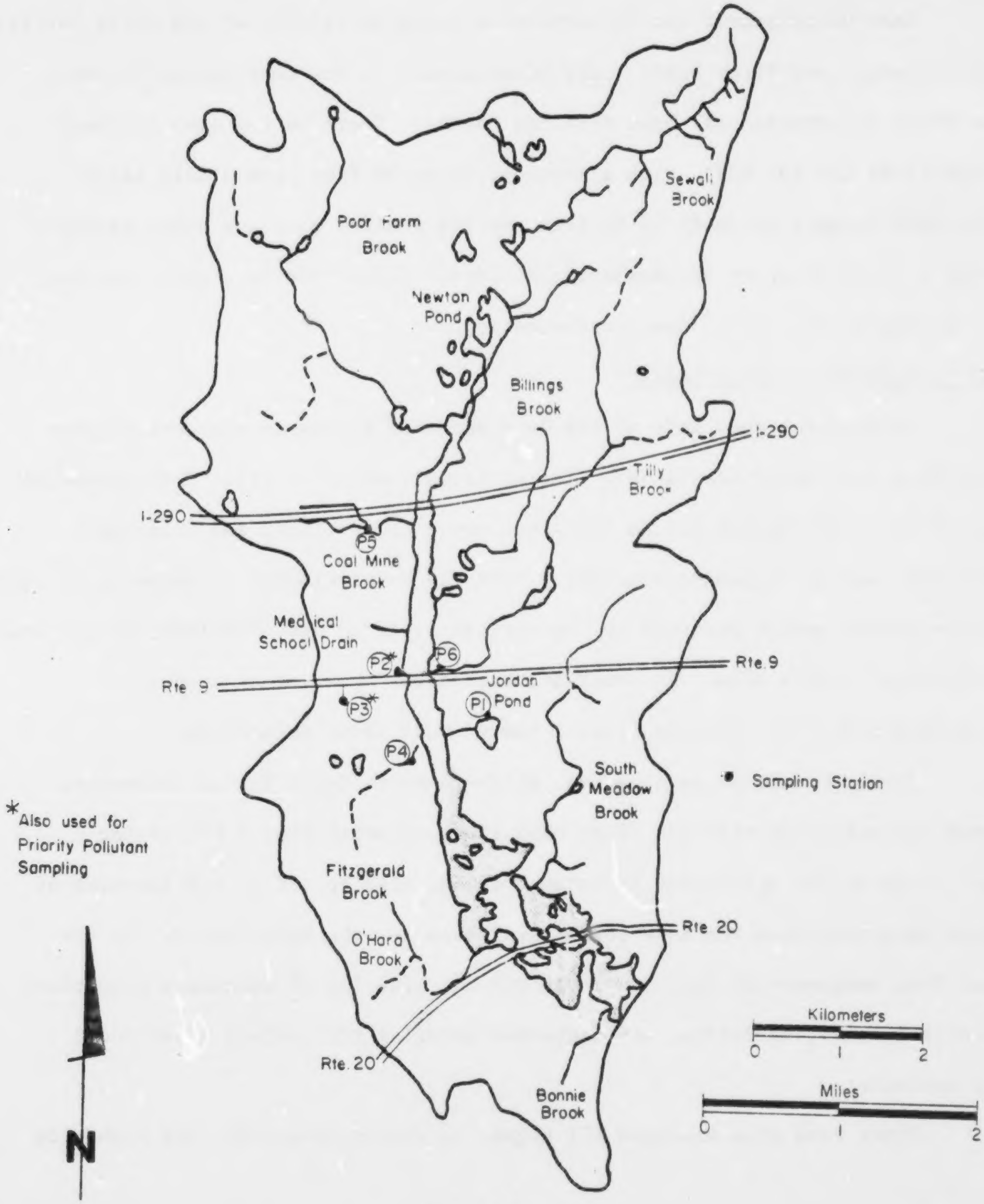

Sewall Brook
Poor Farm Brook
Newton Pond
Billings Brook
I-290
Tilly Brook
I-290
P5
Coal Mine Brook
Medical School Drain
P2*
P6
Rte. 9
Rte. 9
Jordan Pond
P3*
P1
P4
South Meadow Brook
• Sampling Station
*Also used for Priority Pollutant Sampling
Fitzgerald Brook
Rte. 20
O'Hara Brook
Kilometers
0
1
2
Rte. 20
Miles
0
1
2
Bonnie Brook
N

FIGURE II-4

previously described. The quality assurance (QA) plan included sample collection, labeling and transportation; analysis methods ; laboratory analysis procedures; and data management and reporting.

C. Discussion of Results

1. Lake Quinsigamond and Flint Pond

Lake Quinsigamond can be considered morphometrically as two water bodies, Lake Quinsigamond and Flint Pond. Lake Quinsigamond is the deep narrow northern section which is composed of three distinct basins. There is the deep northern basin (stations Q01 and Q02), with a depth of up to 90 feet, the middle basin (station Q03) ranging in depth to 80 feet and the shallow southern basin (station Q04) with a depth of up to approximately 50 feet. Flint Pond is a much shallower basin with depths of 5 to 15 feet predominating.

Spatial Variations in Water Quality

Comparisons were made of the data gathered at the 14 stations located in Flint Pond and Lake Quinsigamond. The stations sampled at Flint Pond showed an average of about 10% higher values for alkalinity, conductivity and chloride than did the Lake Quinsigamond stations. This may be attributed to evapo-concentration during the summer months and also to the greater salinity and alkalinity of the local urban drainage in this area. In contrast, the northernmost station on Lake Quinsigamond (Q12 - Lincoln Street) showed much lower salinities.

There appears to be a general north-to-south trend for an increasing manganese concentration with the Flint Pond stations exhibiting a 67% higher average. This may be attributed to urban drainage effects and to the leaching of dissolved manganese from the lake bottom sediments to the hypolimnion. In the oxidized form manganese is very insoluble but the kinetics of manganese oxidation are relatively slow, therefore, any manganese entering the surface layer would tend to accumulate.

Flint Pond also averaged 47% higher in suspended solids, 61% higher in apparent color, 27% lower in transparency and 14% higher in Kjeldahl nitrogen. Bottom sediment contact and the aquatic weed population are the most likely contributors to these differences. The transparency differences are due to the higher suspended solids and color values.

Parameters that revealed no significant differences are the other nitrogen species, total phosphorus, dissolved phosphorus and chlorophyll-a.

The most apparent difference between the lakes and among stations within the lakes themselves can be seen in bacterial counts. Stations on Lake Quinsigamond averaged 59% higher in fecal coliform counts, with those closest to Route 9 (Q02 & Q06) showing the highest numbers, Station F05 near Route 20 exhibited the highest counts for the Flint Pond stations. These differences reflect proximity to significant sources of pollution.

Vertical Stratification and Hypolimnetic Water Quality

Oxygen and temperature profiles taken at Lake Quinsigamond stations Q01, Q02, Q03 and Q04 provide a basis for describing vertical thermal stratification and hypolimnetic oxygen variations that occur. In 1980 stratification began in mid-April and lasted until early November (approximately 200 days). Oxygen depletion characteristics vary in the three separate hypolimnetic basins. In the deep northern basin anoxic conditions first appeared in early July, as compared with late May in the middle basin and mid-May in the shallow southern basin. This pattern is qualitatively similar to that observed in 1979.

Pockets of relatively high dissolved oxygen concentrations were found in the metalimnion on a few sampling dates in the months of June and July. One explanation for this occurrence is that relatively cool and dense stormwater may have entered the lake and settled to this density layer. Another plausible explanation is the photosynthetic production of oxygen by metalimnetic algal populations. This is indicated by dissolved oxygen measurements which exceeded saturation values and also by transparency measurements which only averaged 10 feet. Algal populations in the metalimnion are important in terms of determining the suitability of the lake for use as a water supply. They also have an impact on hypolimnetic oxygen variations. To better determine the mechanism in operation here, future studies should include vertical chlorophyll-a and/or light absorptance profiles.

Time series of volume-weighted-average oxygen concentrations by station and depth interval were calculated. The estimated and actual hypolimnetic oxygen depletion rates correspond to the spring and early summer period before significant anoxic zones develop. Based upon the volumetric depletion rates, the three basins averaged 140, 130 and 72 days of oxygen supply at spring turnover, respectively, as compared with a stratified period of about 200 days. Oxygen trophic index calculations suggest a late mesotrophic status and that differences in oxygen delpetion among the basins can be explained by morphometric effects.

The sources of oxygen demand are both internal and external. Sedimentation and decay of algae are among the internal while the external sources include sedimentation and decay of stormwater particulate BOD loadings.Loading calculations using suspended solids and BOD estimations indicate that the internal sources of oxygen demand appear to be the most significant.

The development of anoxic conditions in the bottom waters of Lake Quinsigamond is accompanied by significant accumulations of nutrients, iron and manganese in the late summer months. This accumulation results from a combination of release from bottom sediments and decay of settled algae and detritus. Measurements of these constituents taken in hypolimnium zinc during late August and September at each of the four stratified stations indicate values that are considerably in excess of corresponding surface-water concentrations.

The accumulation of phosphorus is of significance due to the potential for internal loading. This is important especially if substantial quantities of dissolved P* reach the oxidized surface layer by diffusion during the stratified

* Phosphorus

period and by mixing during fall overturn or summer storms. Evidence from the data indicates, however, that the hypolimnetic waters are iron rich, therefore, any dissolved P reaching the oxidized zone would be accompanied by reduced iron. Oxidation of this iron results in the relatively rapid formation of insoluble ferric phosphates, which precipitate and settle. Thus, any hypolimnetic phosphorus recycled into the mixed layer would probably not be available to support algal growth. Further evidence of the relative insignificance of this internal phosphorus loading is found in the data collected on the last three sampling dates. Overturn occurred between October 30 and November 13. While substantial accumulations of nutrients and metals are apparent in the hypolimnium samples prior to overturn, surface concentrations of dissolved phosphorus are not increased following fall overturn. The only exception to this is station Q01, which the data indicates had turned over more recently and was probably still undergoing iron oxidation and precipitation. Based upon the nutrient, sediment, and metals data, iron oxidation and precipitation seems to be a reasonable explanation for scouring of dissolved phosphorus from the water column when overturn occurs.

In some cases such as in iron-poor lakes, or in hard-water, anoxic lakes, ferrous ions may be tied up as insoluble ferrous sulfide leaving phosphorus free to migrate into the mixed layer. In Lake Quinsigamond while some sulfate reduction occurs in the anoxic zones, it is not sufficient to exhaust iron supplies. If oxygen depletion occured at a higher rate, more sulfate reduction and iron sulfide generation would occur leading to an increased potential for significant internal recycling of dissolved phosphorus. A key management objective for Lake Quinsigamond should be to prevent this process from occurring by reducing external nutrient loadings.

In littoral areas, internal phosphorus loadings may be generated by other mechanisms. These include exchange with aerobic bottom sediments and the uptake by rooted aquatic macrophytes which eventually decay and release soluble nutrients into the water column. Phosphorus release from aerobic bottom sediments occurs much slower than under anaeorbic conditions due to unfavorable iron phosphate chemistry. Wind-induced resuspension of bottom sediments promotes this type of release. The aquatic weed populations present in shallow areas most likely cause some regeneration of bottom sediment phosphorus.

Sediments

Sediment samples from Lake Quinsigamond, Flint Pond and selected tributaries were collected in September 1980 and July 1981. Tables II-3, II-4 and II-5 summarize the data from these stations. Figure II-3 shows the general location of all sediment sampling stations. Figures II-5 and II-6 show more detail for the location of the lake station above Lincoln Street and the Belmont Street Drain, respectively.

A Sediment Pollution Index (SPI) has been utilized to serve as a reference point in determining the level of pollution present. The Clarke Number, which is a unit of the average abundance of an element in the earth's crust, is employed in this index. The following formula is used to calculate the SPI:

$$SPI = \frac{1}{N} \sum_{i=1}^{N} \frac{\bar{C}i}{CN_i}$$

Where: N = Number of metals included in index
$\bar{C}i$ = Average concentration for Metal i
CN_i = Clarke Number for Metal i

A value of 1.0 is set to represent ideal conditions. Of the tributary sediments, station 5B on Bonnie Brook has by far the highest value and is thus the most polluted. With a value of 21.1, it is nearly three times higher than any other tributary station. The Medical School drain and station 6A on Fitzgerald Brook approach ideal conditions.

The sediment data indicates that the lake is phosphorus enriched. The Phosphorus content of the sediments is several orders of magnitude greater than that of the overlying water because the sediments tend to act as a sink for phosphorus. Phosphorus may be precipitated or sorbed with other chemical components

TABLE II - 3

LAKE QUINSIGAMOND SEDIMENT DATA *

PARAMETER	Sampling Stations Q01	Q02	Q03	Q04	Q12
Total Phosphorus	1500	1625	2700	2300	475
Total Kjeldahl Nitrogen	3325	3950	5075	7275	2875
Aluminum	25300	19400	18900	16474	5377
Arsenic	74	87	115	172	158
Cadmium	1.9	1.8	3.5	8.2	1.9
Chromium	59	49	48	26	15
Copper	47	94	110	161	45
Iron	43400	45300	60000	46300	24100
Lead	434	852	970	566	167
Nickel	57	63	76	60	20
Potassium	4900	3625	2650	1544	630
Zinc	227	326	424	843	152
Sediment Pollution Index (SPI)	12.9	19.0	24.1	27.8	16.3

* Reported in dry weights (mg/kg)

TABLE II-4

FLINT POND SEDIMENT DATA*

PARAMETER	FS1	FS2	FS3	FS4	FS5	FS6	FS7	FS8
	Sampling Stations							
Total Phosphorus	N	1000	850	400	1200	870	1100	2000
Total Kjeldahl Nitrogen	O	16000	15000	11000	10000	8800	3000	9300
Aluminum		12873	9287	14809	17681	13007	20219	110386
Arsenic	S	129	8.8	39	253	142	284	92
Cadmium	A	7.7	2.2	4.0	4.2	4.3	6.0	8.0
Chromium	M	38	18	14	19	15	91	582
Copper	P	138	75	69	93	81	244	3010
Iron	L	19214	18113	18460	44210	19405	19892	42147
Lead	E	346	174	203	358	256	6.0	7.2
Nickel		81	44	45	63	55	124	843
Potassium		1153	530	1217	1473	853	771	903
Zinc		8.5	375	325	358	490	954	7627
Sediment Pollution Index (SPI)		20.2	5.3	9.2	28.3	19.1	29.8	38.9

* Reported in dry weights (mg/kg)

TABLE II-5

LAKE QUINSIGAMOND/FLINT POND
TRIBUTARY SEDIMENT DATA *

Parameter	Sampling Stations										
	Coal Mine Brook 2	Medical School Drain 3	Medical School Drain 3A	Belmont Street Channel 4A	Belmont Street Channel 4B	Belmont Street Channel 4C	Fitz-gerald Brook 6B	Fitz-gerald Brook 6A	Bonnie Brook 5A	Bonnie Brook 5B	Bonnie Brook 5C
Total Phosphorus	2300	325	250	450	1275	2890	750	350	900	1050	500
Total Kjeldahl Nitrogen	1725	2825	2675	2500	2550	2125	2700	2575	3650	4325	2625
Aluminum	7420	3740	1900	3396	3183	3433	38800	3665	39500	34900	3710
Arsenic	27	5.2	4.5	6.3	5.7	5.7	16	4.8	23	24	23
Cadmium	0.00	0.00	0.00	1.7	0.00	0.00	0.00	0.00	1.6	3.5	1.7
Chromium	33	10	10	15	12	10	12	10	527	638	88
Copper	35	22	19	61	134	36	28	25	1813	1718	337
Iron	17800	13800	11400	16980	15250	11843	11663	15660	31310	35100	17030
Lead	126	66	119	458	302	275	131	87	264	302	98
Nickel	43	24	10	27	22	22	8.9	10	330	354	126
Potassium	1518	646	536	560	570	515	745	766	1055	1080	556
Zinc	173	61	54	100	104	89	89	80	396	3540	809
Sediment Pollution Index (SPI)	4.2	1.4	1.9	7.4	4.5	-	3.1	1.6	12.9	21.1	7.1

* Reported in dry weights (mg/kg)

LAKE QUINSIGAMOND (Above Main Street, Shrewsbury) SEDIMENT SAMPLING STATIONS

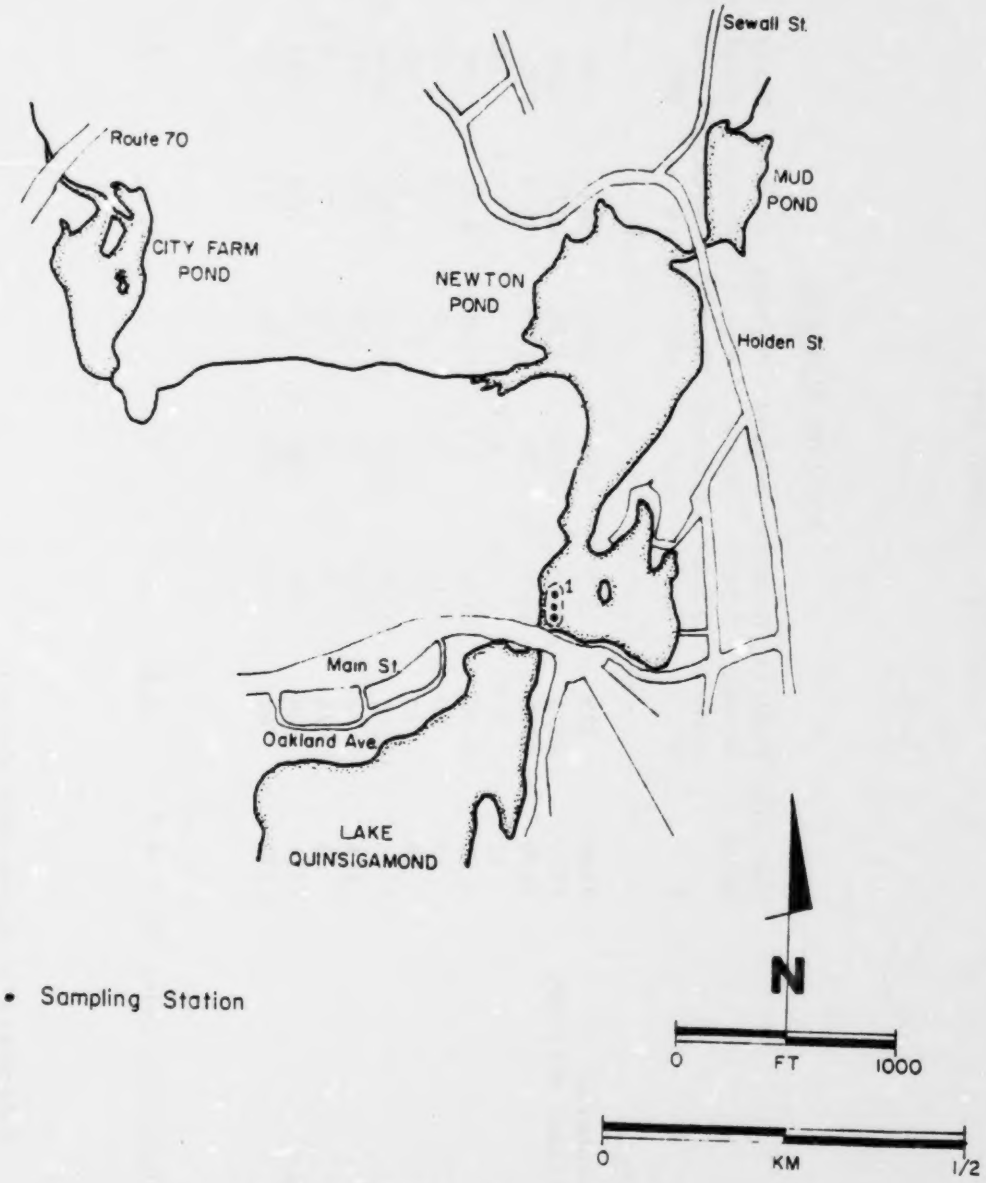
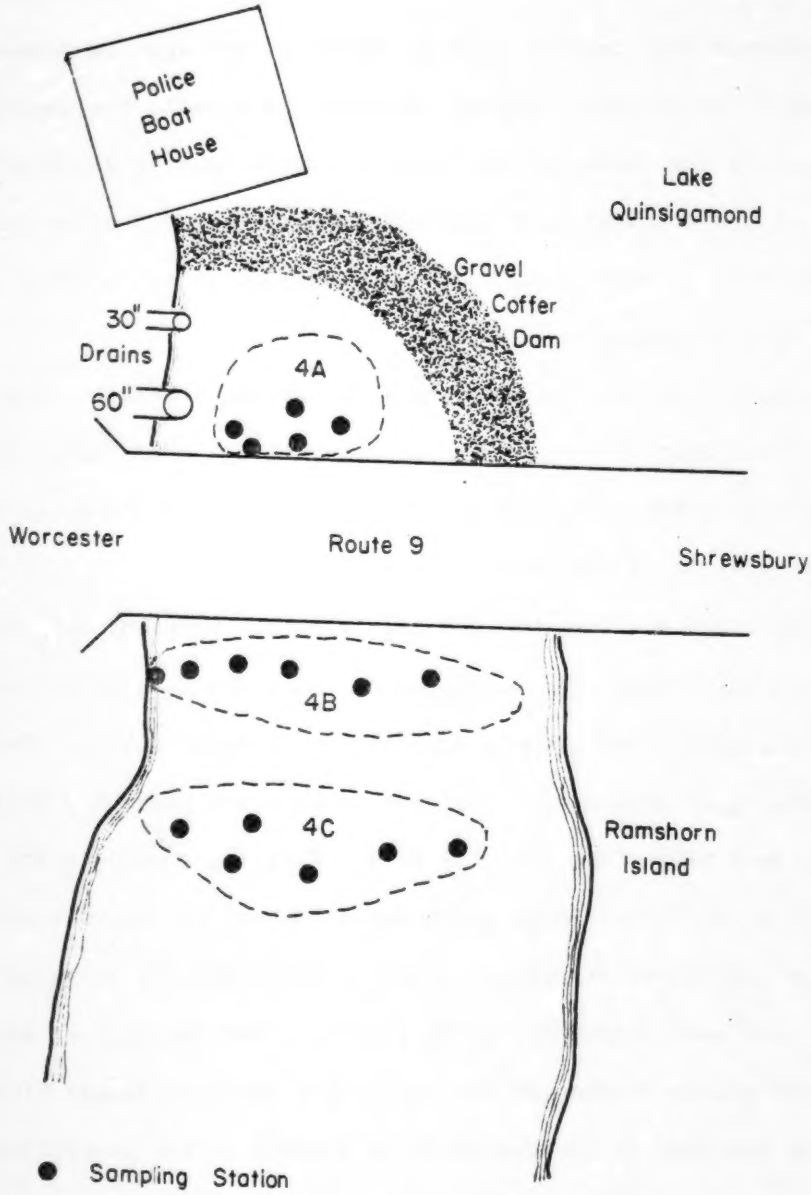

Sewall St.
Route 70
MUD POND
CITY FARM POND
NEWTON POND
Holden St.
1
Main St.
Oakland Ave.
LAKE QUINSIGAMOND
N
• Sampling Station
0
FT
1000
0
KM
1/2

FIGURE II-5

LAKE QUINSIGAMOND

BELMONT ST. DRAIN
SEDIMENT SAMPLING STATIONS


Police Boat House
Lake Quinsigamond
Gravel Coffer Dam
30"
Drains
60"
4A
Worcester
Route 9
Shrewsbury
4B
4C
Ramshorn Island
● Sampling Station

(Drawing not to scale)

FIGURE II-6

such as aluminum, iron and manganese These complexes are relatively insoluble and settle to the lake bottom. Significant amounts of aluminum and iron are found in the sediments increasing the efficiency of phosphorus precipitation. Aluminum as well as potassium,which is also found in high amounts,are associated with the mineral fraction of the sediment and can be regarded as being directly proportional to the intensity of erosion.

The lake sediments also contain a large amount of nitrogen as measured by the Total Kjeldahl Nitrogen data. Organic nitrogen is usually the dominant form and is a function of the amount of particulate organic matter deposited.

The effects of the nutrient-rich sediment are most clearly evidenced in the excessive weed growth both in Flint Pond and in the shallow areas in Lake Quinsigamond, north of Main Street.

Sediments typically act as the ultimate sink for heavy metals. Comparisons with the 1971 data reveal that in most instances heavy metal levels have risen significantly over the past ten years. Station Q03 near Route 9 shows the largest increase with nearly three times the levels found in 1971.

Relatively high levels of arsenic for the tributary stations were found at Coal Mine Brook, Fitzgerald Brook, and Bonnie Brook. Arsenic is used in soap. detergents, pesticides, herbicides and in the manufacture of metal alloys. Detergents can contain 70 to 80mg/kg of arsenate in conjunction with the phosphate buffer and wash water concentrations range from 5 to 100 mg/l. This might account for the high levels found at Coal Mine Brook which has a history of sanitary and storm drain line misconnections and at Fitzgerald Brook in which several pipes of unidentified origin have been observed. Wyman Gordon, a manufacturer of metal forgings, may use arsenic in its operations accounting for the levels found in Bonnie Brook. One of the mechanisms employed in the chemistry of arsenic is the precipitation of arsenate with metal ions particularly hydrous iron oxides. Since there is an abundance of iron within the lake, ferric arsenate is easily formed. In this form it is very insoluble and thus accumulates in the sediments.

Extremely high levels of chromium were present in Bonnie Brook. A high of 638 mg/kg was found which is approximately 50 times higher on the average than any other tributary station. The main source of this metal is in all likelihood from the industrial processes performed at Wyman-Gordan.

Copper was found in relatively high amounts at Bonnie Brook, Belmont Street, and Lake Stations Q02, Q03 and Q04. Bonnie Brook levels were extremely high more than ten times the Belmont Street station and 60 times higher than the other tributary stations. There appears to be a copper concentrated area in the vicinity of Belmont Street and lake stations Q02 and Q03. Copper has a strong affinity to organic matter and hydrous iron and manganese oxides. Sorption to these substances which are all abundant in the lake results in a reduction of dissolved species to the solid phase and accumulation in the sediments.

Contamination from lead is attributed to automotive exhaust, motor boat exhaust and industrial discharges. Lead is used in gasoline additives, metal products and agricultural pesticides. Auto exhaust results in particulate fallout from the atmosphere. Lead may then settle out as the result of gravity and may be carried to the aquatic environment by street runoff. As can be expected, high levels were found near Route 9 & Belmont Streets at stations Q02 and Q03 and at station Q01 which is located near I-290. There has been a dramatic increase in lead levels over the past ten years. Station Q03 shows the largest increase, nearly seven times the amount found in 1971 while station Q01 shows more than a twofold increase.

Nickel and zinc levels in the lake and tributary stations were all within a reasonable range of each other with the exception of Bonnie Brook which exhibited much higher levels.

Sediment sampling data from Flint Pond , summarized in Table II-4, indicate significantly higher levels than Lake Quinsigamond particularly nitrogen. Heavy metal levels are generally similar with the exception of stations FS7 and FS8. These stations are both in the area of the Bonnie Brook discharge and indicate a significant impact from upstream point and/or nonpoint metals sources. Arsenic concentrations in open-water stations including FS2, FS5,FS6 and FS7 are significantly higher than those found in Lake Quinsigamond. This buildup reflects herbicide applications (sodium arsenite) made between 1971 and 1978. Sediments in Flint Pond can be expected to play a far more significant role in terms of internal nutrient cycling and subsequent growth of aquatic vegetation than do the sediments in Lake Quinisigamond.

Eutrophication

Nutrient enrichment has important water quality effects on Lake Quinsigamond and Flint Pond,and is regarded as one of the most severe problems potentially facing these water bodies.

A typical seasonal succession of algal species which is regulated by temperature, light, and nutrient factors, is evident. Diatoms were dominant in spring and late fall, greens in June and early July, and bluegreens in late summer and early fall. Spring diatom dominance ended in early June with the depletion of surface silica levels. Bluegreens became dominant after inorganic nitrogen levels were depleted in early August, which is consistent with their nitrogen fixing ability.

Algal biomass typically contains 7 parts nitrogen to 1 part phosphorus by weight. Analysis of the data indicates nitrogen limitation in the late summer. However, on one sampling date during this period phosphorus was found to be the limiting factor suggesting that elements other than general seasonal trends may regulate the controlling nutrient. Storm event patterns may contribute to the nitrogen/phosphorus variations. An apparent increase in the nitrogen/phosphorus ratios coincided with a week of dry weather in which there were little significant external nutrient loadings. Significantly higher levels of total phosphorus and dissolved phosphorus were found on "wet" days as compared with "dry" days.

An algal assay bottle test which is utilized to indicate phosphorus, nitrogen or trace metal nutrient limitation was performed in April, 1981. The growth response of the algal organism Selenastrum capricornutum to additions of phosphorus, nitrogen and EDTA* is used for this purpose. An analysis of Flint Pond indicated a very slight phosphorus limitation with either a micronutrient limitation or heavy metal toxicity. Stations Q01 and Q03 on Lake Quinsigamond showed a nitrogen limitation and either micronutrient limitation or heavy metal toxicity. Tests conducted with EDTA give a definite indication that metals have a limiting effect on algal production.

Based on modeling analyses performed by META Systems using both the 1971 and 1979-1980 data bases, dissolved phosphorus was determined as the dominant form biologically available for algal growth. Particulate phosphorus apparently plays a very minor direct role. Investigations reported in the literature suggest particulate phosphorus will generally settle at too fast a rate to be useful to algae in the upper levels of the lake. The abundance of iron in the lake will insure settling of phosphorus by forming iron phosphate which will readily settle. In addition particulate phosphorus is more stable than particulate nitrogen and therefore the rate at which particulate phosphorus can be converted to a biologically available form is less.

To control algal cycles, phosphorus was identified as the limiting factor. The N:P ratios for most of the year were greater than the 7:1 ratio found in algae biomass. Short periods of lower N:P ratios were linked to summer storm periods when runoff contributed nutrients at N:P ratios of less than 4:1. The reversal may be important for short periods, however, the reversals of the N:P ratio were considered less important than the long term importance of available phosphorus. This conclusion is supported by the settling column results which show runoff nitrogen to settle more slowly than phosphorus and therefore the N:P ratio will quickly increase as phosphorus settles out.

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*EDTA - Ethylmediamine Tetraacetic Acid

Trophic State Indices

Trophic state indices were calculated from surface-layer measurements of total phosphorus, transparency and chlorophyll-a. The chlorophyll-a index is not significantly influenced by lake or weather group because the time scale of biological response to conditions is relatively long. Algae respond to seasonal conditions rather than individual storm events. Systemic effects of weather on the phosphorus index are apparent in both lakes. Phosphorus levels tended to be higher on wet days. While there are some wet-weather effects on the transparency index, they are not as strong as the effects on total phosphorus. Agreement among the chlorophyll, transparency, and hypolimnetic oxygen indices is within a reasonable error margin.

These indices suggest a late mesotrophic-early eutrophic state for Lake Quinsigamond. The eutrophication state of Flint Pond would be approximately the same except for the presence of weeds in the shallow waters which elicits a classification of eutrophic.

Bacteria

Class B standards state that fecal coliform levels should not exceed 200 organisms/100 ml and total coliforms should not be in excess of 1000 organisms/100 ml. No fecal coliform violations were observed in Flint Pond. In Lake Quinsigamond, however, fecal counts exceeded 200 in two samples out of a total of 104. A tendancy was observed for both total and fecal coliform levels to increase in the main lake during wet weather. Counts tended to be highest in the lake stations near Route 9 which is nearest the most concentrated source, the Belmont Street Drain. Unlike Quinsigamond stations, the higher coliform counts measured at Flint Pond station F05 (Route 20) are not associated with wet weather and may be related to dry-weather tributary inputs or septic systems.

While several of the tributary stations had excessive counts, lake levels averaged more than an order of magnitude below the state Class B standard. This is a result of dilution, sedimentation and the relatively rapid die-off of the organisms in the lake. Based upon the standard, potential hazards for body contact recreation occur only in localized areas of the lakes after significant storm events. The existing data suggests that it would be unwise to permit body contact recreation in the north basin of the lake during or immediately following significant storm events.

Bacteria counts are also of significance in relation to possible use of the lakes as a reserve water supply. The State Class A standard is 50 total coliforms per 100 ml as a monthly geometric mean. Flint Pond counts (mean 46/100 ml) barely meet the standard, whereas Quinsigamond counts (mean 62/100 ml) just exceed it. More intensive storm-event monitoring would be needed to better define the suitability of various areas of the lake for water supply use.

Fisheries

A fisheries survey was conducted in conjunction with the Massachusetts Division of Fisheries and Wildlife in order to assess the population and qualitative character of the fish species present in Lake Quinsigamond and Flint Pond. Fish samples were collected by electroshocking which temporarily stuns the fish population present in a particular area. A representative sampling of the population that is present can then be evaluated.

Fish tissue samples were sent to the Lawrence Experimental Station for analysis of the following contaminants: mercury, arsenic, lead, zinc, cadmium and chromium. Results of those analysis are summarized in Tables II-6 and II-7.

Natural environments are populated by a number of different species each with its own particular features and tolerance capabilities. A wide variety of fish ranging from the bottom-dwelling bullhead to the predatory pickerel, and trout were found in the lake. A high diversity is

TABLE II-6

FISH TISSUE DATA
BY LOCATION AND SPECIES

Flint Pond (FP)

Species			Metal			
	Arsenic	Cadmium	Chromium	Lead	Mercury	Zinc
Bluegill	0.00	0.36	0.00	0.00	0.14	8.9
Brown Bullhead	0.00	0.25	0.00	0.80	0.14	6.3
White Perch	0.00	0.30	0.00	0.30	0.22	4.2
Yellow Perch	0.00	0.30	0.30	0.60	0.14	7.5
Pumpkinseed	0.00	0.26	0.00	0.51	0.12	6.4
Smallmouth Bass	0.00	0.37	0.00	1.9	0.31	15.0
Largemouth Bass	0.00	0.26	0.00	0.26	0.57	3.9
Black Crappie	0.00	0.00	0.00	0.00	0.27	14.0
Pickerel	0.00	0.30	0.00	0.30	0.23	6.4
Carp	0.00	0.00	0.00	0.00	0.08	7.5
Mean	0.00	0.24	0.03	0.47	0.22	8.0

Lake Quinsigamond - Northern Basin (LQ-N)

Species	Arsenic	Cadmium	Chromium	Lead	Mercury	Zinc
Bluegill	0.00	0.23	0.00	0.95	0.16	8.3
White Perch	0.00	0.00	0.00	0.85	0.51	8.2
Yellow Perch	0.00	0.00	0.00	1.2	0.10	6.0
Smallmouth Bass	0.00	0.00	0.28	0.86	0.18	4.9
Largemouth Bass	0.00	0.32	0.00	1.3	0.52	7.9
Pickerel	0.00	0.00	0.00	1.1	0.33	5.3
White Sucker	0.00	0.24	0.00	0.48	0.27	6.6
Mean	0.00	0.10	0.07	1.0	0.30	6.6

Lake Quinsigamond - Southern Basin(LQ-S)

Species	Arsenic	Cadmium	Chromium	Lead	Mercury	Zinc
Bluegill	0.00	0.28	0.00	1.1	0.06	11.0
Pumpkinseed	0.00	0.00	0.34	0.34	0.97	11.0
White Perch	0.00	0.00	0.30	0.91	0.33	22.0
Yellow Perch	0.00	0.00	0.00	0.65	0.20	8.4
Smallmouth Bass	0.00	0.28	0.28	0.83	0.22	5.3
Largemouth Bass	0.00	0.28	0.00	0.56	0.11	4.8
Pickerel	0.00	0.00	0.00	0.88	0.19	12.0
Mean	0.00	0.12	0.13	0.75	0.30	10.6

TABLE II-7

FISH TISSUE DATA BY SPECIES AND LOCATION

Species	Metal					
	Arsenic	Cadmium	Chromium	Lead	Mercury	Zinc
*** Bluegill**						
FP	0.00	0.36	0.00	0.00	0.14	8.9
LQ-N	0.00	0.23	0.00	0.95	0.16	8.3
LQ-S	6.00	0.28	0.00	1.1	0.06	11.0
Mean	0.0	0.29	0.0	0.68	0.12	9.4
Pumpkinseed						
FP	0.00	0.26	0.00	0.51	0.12	6.4
LQ-S	0.00	0.00	0.34	0.34	0.97	11.0
Mean	0.0	0.13	0.17	0.42	0.55	8.7
White Perch						
FP	0.00	0.30	0.00	0.30	0.22	4.2
LQ-N	0.00	0.00	0.00	0.85	0.51	8.2
LQ-S	0.00	0.00	0.30	0.91	0.33	22.0
Mean	0.0	0.1	0.1	0.68	0.35	11.4
Yellow Perch						
FP	0.00	0.30	0.30	0.60	0.14	7.5
LQ-N	0.00	0.00	0.00	1.2	0.10	6.0
LQ-S	0.00	0.00	0.00	0.65	0.20	8.4
Mean	0.0	0.1	0.1	0.82	0.15	7.3
Pickerel						
FP	0.00	0.30	0.00	0.30	0.23	6.4
LQ-N	0.00	0.00	0.00	1.1	0.33	5.3
LQ-S	0.00	0.00	0.00	0.88	0.19	12.0
Mean	0.0	0.1	0.0	0.76	0.25	7.9
Largemouth Bass						
FP	0.00	0.26	0.00	0.26	0.57	3.9
LQ-N	0.00	0.32	0.00	1.3	0.52	7.9
LQ-S	0.00	0.28	0.00	0.56	0.11	4.8
Mean	0.0	0.29	0.0	0.71	0.4	5.5
Smallmouth Bass						
FP	0.00	0.37	0.00	1.9	0.31	15.0
LQ-N	0.00	0.00	0.28	0.86	0.18	4.9
LQ-S	0.00	0.28	0.28	0.83	0.22	5.3
Mean	0.0	0.22	0.20	1.2	0.24	8.4

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* FP: Flint Pond
LQ-N: Lake Quinsigamond - Northern Basin
LQ-S: Lake Quinsigamond - Southern Basin

indicated where a great many different species are present which will utilize the available food intensely. A progressive decrease in the favorability of the environment is often associated with a low diversity and a progressive increase in population density among those species. Lake Quinsigamond and Flint Pond exhibit a high diversity containing both carp which can tolerate very polluted waters and trout and bass which require relatively clean and cold water.

Comparisons with fisheries surveys performed in 1944 and 1971 reveal that not much appreciable change has taken place in the fish species complex.

The suitability of the lake for habitation by trout is determined by a combination of two factors, the amount of oxygen present and temperature. The dissolved oxygen concentration should equal or exceed 5 mg/liter and the temperature should be less than 20°C. This is assuming that other chemical factors such as metal toxicity, ammonia toxicity and pH are not limiting. The temperature criterion tends to be limiting in the summer while the oxygen criterion becomes increasingly important as hypolimnetic oxygen depletion occurs during the stratified period. A critical period is reached in August and September when surface temperatures have peaked and hypolimnetic oxygen depletion is the most severe. Trout habitat at this time is restricted to the thermocline (20-30 feet) which is only a small portion of the total lake volume. The potential for trout fishery could be improved by reducing the oxygen depletion rates through nutrient loading controls.

2. Tributary Water Quality

Monitoring of the tributaries to Lake Quinsigamond and Flint Pond was conducted on a bi-weekly basis from April through November, 1980. Six of the major tributaries were selected for additional monitoring to include the upper reaches of these tributaries. Monthly monitoring was conducted at each of these twenty stations from September, 1980 to June, 1981. As previously discussed, sediment samples were collected at a number of tributaries.

The following sections provide a description of each tributary and an assessment of their respective water quality conditions.

POOR FARM BROOK

The Poor Farm Brook drainage area is located at the northern end of the Lake Quinsigamond watershed and includes portions of West Boylston, Boylston, Shrewsbury and Worcester (see Figure II-7). Poor Farm Brook and Newton Pond are the two major tributaries to the northern pond of Lake Quinsigamond.

Poor Farm Brook originates in West Boylston at the outlet of a small pond located between Hartwell and Shrewsbury Streets. From its source, the Brook flows south along Shrewsbury Street along the power line right-of-way at the base of Worcester County Jail and Hospital property. A small brook draining the cattle farm pasture plus the surface drainage from the jail parking lot and facility enters Poor Farm Brook just before it passes under Briar Lane and into the City of Worcester. Below Briar Lane, the Brook flows through the Worcester Country Club where it flows through three small ponds (erstwhile course water hazards) and is joined by another brook which drains most of the northern corner of Worcester known as the Summit. Poor Farm runs under East Mountain Street as it exits the Country Club, behind the Mountain Village Apartments and under Clark Street. A small brook draining a portion of the Lincoln Village Apartments Complex and the St. Nicholas Avenue School area is culverted underground to Poor Farm Brook below Clark Street. From here, Poor Farm Brook runs parallel between Tacoma Street and the Great Brook Valley Housing Project and East Mountain Street into Shrewsbury as it crosses under East Mountain Street, then under Route 70 and into City Farm Pond. The Brook turns east from the outlet of City Farm Pond. along the Goddard Industrial Park and into Lake Quinsigamond's northern pond. Another small, intermittant brook originating behind the jail in West Boylston runs into Poor Farm at East Mountain Street via overland flow.

POOR FARM BROOK SAMPLING STATIONS

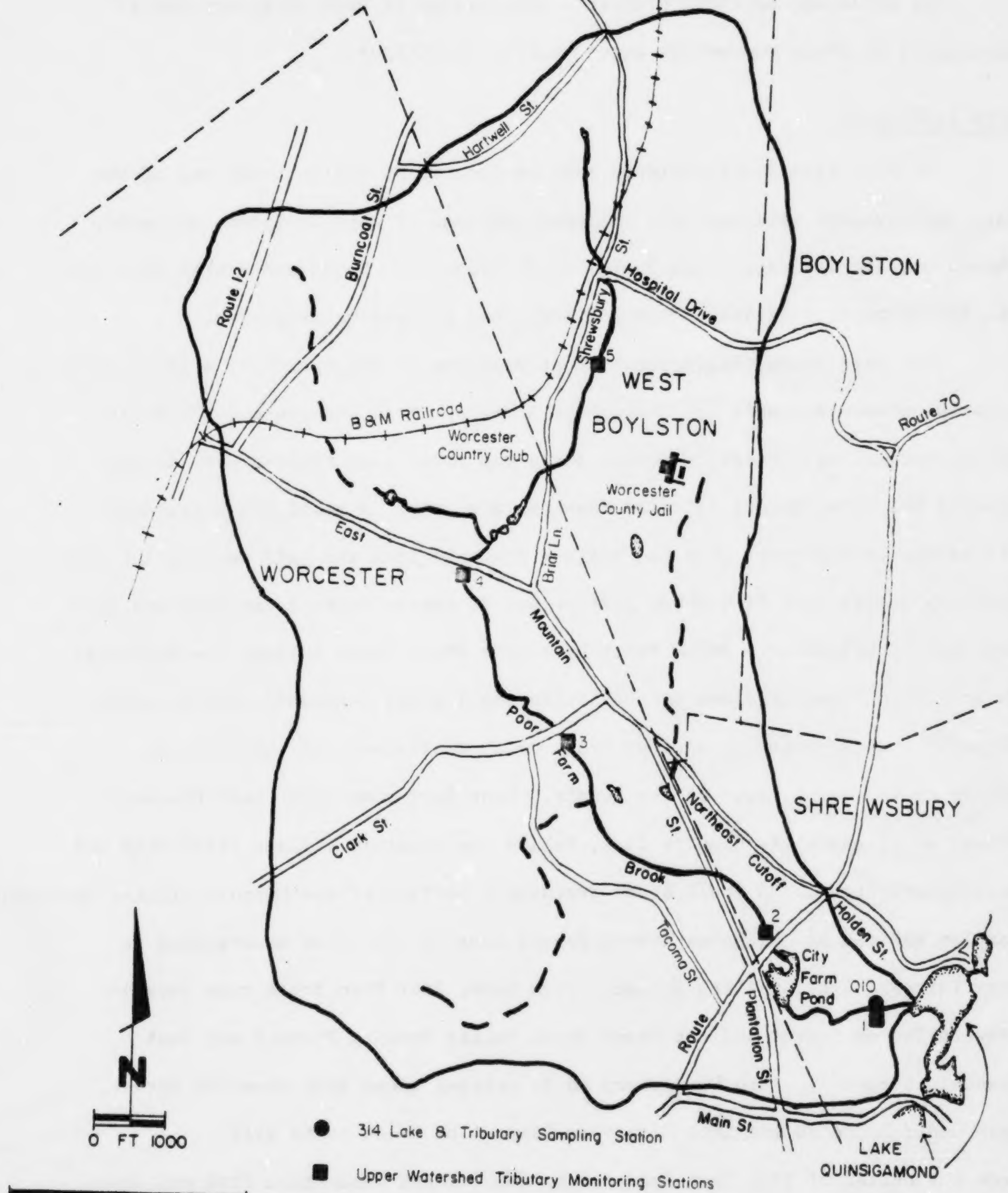
Hartwell St.
Burncoat St.
Route 12
Shrewsbury St.
Hospital Drive
BOYLSTON
5
WEST BOYLSTON
B&M Railroad
Worcester Country Club
Route 70
Worcester County Jail
East
Mountain
Briar Ln.
WORCESTER
4
Poor
Farm
Brook
3
Clark St.
St.
Northeast Cutoff
SHREWSBURY
Holden St.
Tacoma St.
2
City Farm Pond
Q10
1
Route
Plantation St.
Main St.
LAKE QUINSIGAMOND
N
0 FT 1000
0 KM 1
314 Lake & Tributary Sampling Station
Upper Watershed Tributary Monitoring Stations

FIGURE II-7

Land use in the watershed ranges from agricultural pasture land to active recreation (major Worcester area golf course) to intense urban development including single and multi-family residential development in addition to light and medium industrial and commercial development.

Five sampling stations were located on Poor Farm Brook under the Upper Watershed monitoring program. Station Q10, at the mouth of the brook, was monitored under the 314 Lake/tributary program. Station Q10 and STA #1 are the same station sampled under the two sampling programs. No sediment samples were collected from Poor Farm Brook. Figure II-7 shows the location of all sampling stations on this brook. Water quality data from the Upper Watershed Monitoring program is displayed on tables II-8 through II-12. Table II-13 summarizes the average concentrations of each parameter at each station over the survey period. Table II-14 provides a comparison of data generated by the two monitoring programs at the same sampling station, Q10 and STA#1. This comparison suggests a strong seasonal variation as the sampling period associated with station Q10 is "summer" oriented while STA#1 is predominantly "winter" conditions. These periods might also be considered to represent "dry" and "wet" conditions, respectively. Marked increases in chloride conductivity and other dissolved constituents tend to confirm this comparison. Bacteria data also suggest a seasonal trend.

Monitoring data for the month of June, 1981 at STA 2 and STA 1 dramatically indicate the impact of a raw sewage discharge to the brook. Due to a collapsed section of pipe, the contents of the line, which handles an average 2.0 million gallons per day of sewage, had to be pumped out of the line and discharged directly to the brook until repairs could be effected. Bacteria levels were held in check to a certain degree by in-stream chlorination and detention in City Farm Pond. Although Poor Farm Brook was significantly degraded due to this incident, the actions taken at City Farm Pond prevented any serious immediate problems from occurring in Lake Quinsigamond.

TABLE II-8

POOR FARM BROOK - STATION 5
HOSPITAL DRIVE (WEST BOYLSTON)
WATER QUALITY DATA (mg/1)

Parameter(1)	Sept 1980	Oct	Nov	Dec	Jan 1981	Feb	March	April	May	June	Avg.	Standard Deviation
pH (Standard Units)	6.5	6.7	6.5	6.8	6.7	6.6	6.6	7.1	6.5	7.2	6.7	0.2
Dissolved Oxygen	9.2	10.0	11.6	12.2	11.3	11.2	11.8	10.2	7.0	7.9	10.2	1.7
Temperature ^{o}C	13.0	4.5	1.0	-	0.0	0.0	0.0	10.0	15.0	15.0	6.5	6.7
Total Solids	371	320	220	220	250	270	140	180	80	180	223	86
Suspended Solids	28.7	13.0	-	-	-	-	-	-	-	-	-	-
Total Hardness	81	82	52	69	71	69	50	60	40	60	63	14
Chloride	159	88	76	105	124	70	61	60	65	-	90	34
Conductivity (2)	500	550	260	375	465	420	185	260	190	240	344	134
Ammonia-Nitrogen	0.25	0.65	1.2	1.05	0.78	1.25	0.56	0.65	0.15	0.95	0.75	0.37
Nitrate-Nitrogen	1.4	0.7	0.6	0.9	1.9	1.1	0.8	1.3	0.4	0.9	1.0	0.4
Nitrite-Nitrogen	0.001	-	0.001	0.003	0.001	<.001	0.001	0.000	-	0.004	0.002	0.001
Total Phosphorus	0.02	0.04	0.02	0.04	0.08	0.08	0.00	0.03	-	0.01	0.04	0.03
Total Alkalinity	36	35	27	38	33	90	38	32	22	37	39	19
Total Coliform (3)	800	1100	200	700	<100	20	10	700	440	10000	1407	1037
Fecal Coliform	80	30	30	140	70	10	<10	580	190	1900	304	581
Fecal Strep	110	50	30	10	10	60	<10	10	2500	19000	469	924

1) All units reported as mg/1 except bacteria and conductivity or unless otherwise noted.
2) Conductivity reported as umhos/cm.
3) Bacteria reported as colonies per 100 ml.

TABLE II-9

POOR FARM BROOK - STATION 4
EAST MOUNTAIN STREET, BELOW GOLF COURSE
WATER QUALITY DATA (mg/1)

Parameter (1)	Sept 1980	Oct	Nov	Dec	Jan 1981	Feb	March	April	May	June	Avg.	S.D.
pH (Standard untis)	6.3	6.7	6.8	6.9	7.2	6.9	7.0	7.4	6.9	7.3	6.9	.3
Dissolved Oxygen	9.7	10.2	11.9	10.4	13.3	13.5	12.7	11.0	8.6	8.4	11.0	1.8
Temperature °C	15.0	5.5	2.0	-	0	1.0	3.0	11.0	15.0	17.0	7.7	6.8
Total Solids	295	208	254	194	262	174	170	216	92	200	207	66
Suspended Solids	20.1	10	-	-	-	-	-	-	-	-	-	-
Total Hardness	66	71	81	87	80	71	70	66	52	80	72	10
Chloride	94	51	62	87	144	64	64	68	71	-	78.3	27.9
Conductivity (2)	350	450	315	360	350	360	205	290	210	260	315	67
Ammonia-Nitrogen	0.01	0.05	0.09	0.13	2.29	0.45	0.11	0.07	0.04	0.15	0.12	0.73
Nitrate-Nitrogen	1.0	1.0	1.5	1.9	1.0	1.9	1.6	1.5	.6	1.4	1.3	0.5
Nitrite-Nitrogen	0.001	-	0.001	0.002	0.001	0.002	<.001	<.001	-	0.003	0.002	0.0008
Total Phosphorus	0.12	0.01	0.01	0.01	0.08	0.15	0.04	0.01	-	0.01	0.05	0.05
Total Alkalinity	42	40	42	44	44	35	57	43	27	46	42	8
Total Coliform (3)	700	300	100	100	<100	70	20	70	950	1900	431	681
Fecal Coliform	40	30	<10	<10	<10	30	<10	40	260	<100	54	77
Fecal Strep	200	40	20	150	<10	150	10	10	2100	2500	507	788

1) All units reported as mg/1 except bacteria and conductivity or unless otherwise noted.
2) Conductivity reported as umhos/cm.
3) Bacteria reported as colonies per 100 ml.

TABLE II-10

POOR FARM BROOK - STATION 3
STAFF GAGE BELOW CLARK STREET
WATER QUALITY DATA (mg/1)

Parameter(1)	Sept 1980	Oct	Nov	Dec	Jan 1981	Feb	March	April	May	June	Avg.	S.D.
pH (Standard units)	6.6	7.0	7.0	6.9	N	7.1	7.0	7.3	6.9	7.3	7.0	.2
Dissolved Oxygen	10.6	11.9	13.6	8.4	O	14.2	12.8	11.1	9.1	8.9	11.2	1.9
Temperature ^oC	12.0	5.5	1.0		T	0	4.0	11.0	15.0	18.0	8.3	6.6
Total Solids	343	227	300	206		204	170	200	110	220	220	68
Suspended Solids	20.7	11.0	-	-	S	-	-	-	-	-	-	-
Total Hardness	65	69	83	73	A	74	70	64	56	84	71	9
Chloride	101	65	96	102	M	75	70	65	68	-	80	18
Conductivity(2)	450	450	400	350	P	365		280	230	310	354	79
Ammonia-Nitorgen	0.08	0.03	0.04	0.13	L	0.31	0.10	0.06	0.05	0.31	0.12	0.11
Nitrate-Nitrogen	2.4	1.1	1.6	1.8	E	2.4	1.8	1.4	.6	1.6	1.63	.81
Nitrite-Nitorgen	0.005	-	0.001	0.002	D	0.002	<.001	0.001	-	0.007	0.003	0.002
Total Phosphorus	0.18	0.03	0.01	0.04		0.07	0.04	0.01	-	0.05	0.05	0.05
Total Alkalinity	34	42	38	42		65	59	34	24	42	42	13
Total Coliform(3)	1300	800	1100	200		600	12500	1000	4000	35000	6278	11443
Fecal Coliform	550	50	110	<100		270	3600	60	300	5600	1182	2007
Fecal Strep	720	200	90	-		140	10	40	1750	5000	994	1722

1) All units reported as mg/l except bacteria and conductivity or unless otherwise noted.
2) Conductivity reported as umhos/cm.
3) Bacteria reported as colonies per 100 ml.

TABLE II-11

POOR FARM BROOK - STATION 2
ROUTE 70 BRIDGE
WATER QUALITY DATA (mg/1)

Parameter (1)	Sept 1980	Oct	Nov	Dec	Jan 1981	Feb	March	April	May	June	Avg.	S.D.
pH (Standard units)	6.5	6.6	6.7	6.8	N	7.0	6.8	7.2	7.0	6.9	6.8	.2
Dissolved Oxygen	10.2	11.7	13.0	13.3	O	14.1	13.0	10.8	9.4	4.2	11.1	3.0
Temperature °C	11.5	5.5	1		T	0	4	12	15	19	8.5	6.9
Total Solids	278	202	306	190		-	148	210	110	240	210.5	64.4
Suspended Solids	19.4	9.5	-	-	S	-	-	-	-	-	-	-
Total Hardness	50	70	75	71	A	79	62	63	56	96	69	14
Chloride	77	59	94	96	M	65	60	65	70	-	73	15
Conductivity (2)	300	400	440	340	P	350	-	290	210	430	345	78
Ammonia-Nitrogen	0.14	0.04	0.11	0.07	L	0 .29	0 .09	0 .08	0 .05	6.95	0 .87	2.28
Nitrate-Nitrogen	0.6	1.2	1.7	1.8	E	2.1	1.8	1.4	0 .8	1.9	1.5	0 .5
Nitrite-Nitrogen	0.002	-	0.001	0.002	D	0 .001	<.001	0 .001	-	0.005	0.002	0 .001
Total Phosphorus	0.04	0.01	0.04	0.04		0 .11	0.00	0.04	-	2.0	0.29	0 .69
Total Alkalinity	29	31	34	33		55	54	33	26	88	43	20
Total Coliform (3)	1100	12000	2100	300		100	400	12500	1400	100000	14433	32468
Fecal Coliform	100	90	1975	200		<100	380	2500	440	20000	2865	6487
Fecal Strep	310	110	900	40		280	20	1490	1250	2500	767	847

1) All units reported as mg/1 except bacteria and conductivity or unless otherwise noted.
2) Conductivity reported as umhos/cm.
3) Bacteria reported as colonies per 100 ml.

TABLE II-12

POOR FARM BROOK - STATION 1
BEHIND SHREWSBURY INDUSTRIAL PARK
WATER QUALITY DATA (mg/1)

Parameters (1)	Sept 1980	Oct	Nov	Dec	Jan 1981	Feb	March	April	May	June	Avg.	S.D.
pH (Standard units)	N	6.3	6.8	6.8	N	6.8	5.9	6.9	6.9	6.7	6.6	0.4
Dissolved Oxygen	O	5.1	10.2	12.9	O	13.8	13.1	11.0	8.7	2.8	9.7	4.0
Temperature °C	T	5.5	2	-	T	1	4	11	15	19.5	8.3	6.2
Total Solids		257	306	272		160	140	240	100	260	217	74
Suspended Solids	S	20.5	-	-	S	-	-	-	-	-	-	-
Total Hardness	A	119	72	78	A	71	71	70	52	88	78	18
Chloride	M	42	105	112	M	65	75	72	73	-	78	24
Conductivity (2)	P	500	990	610	P	340	235	390	240	690	499	257
Ammonia-Nitrogen	L	0.13	0.11	0.07	L	0.22	0.11	0.11	0.08	0.78	0.20	0.24
Nitrate-Nitrogen	E	0.4	1.1	1.8	E	2.0	1.9	1.5	0.6	4.8	1.8	1.4
Nitrite-Nitrogen	D	-	0.001	0.003	D	0.003	<.001	0.002	-	0.003	0.002	0.001
Total Phosphorus		0.04	0.06	0.04		0.15	0.00	0.04	-	1.6	0.28	0.54
Total Alkalinity		48	33	33		29	43	40	25	48	37	9
Total Coliform (3)	D	900	900	300		300	900	7900	4200	100000	14425	34678
Fecal Coliform	R	10	450	30		50	750	1040	780	12500	1951	4280
Fecal Strep	Y	80	120	10		230	10	290	2500	12000	1905	4164

1) All units reported as mg/1 except bacteria and conductivity or unless otherwise noted.
2) Conductivity reported as umhos/cm.
3) Bacteria reported as colonies per 100 ml.

TABLE II-13

AVERAGE DATA VALUES (mg/1)
POOR FARM BROOK

Parameter	STA 5	STA 4	STA 3	STA 2	STA 1
pH (Std. Units)	6.7	6.9	7.0	6.8	6.6
Dissolved Oxygen	10.2	11.0	11.2	11.1	9.7
Temperature °C	6.5	7.7	8.3	8.5	8.3
Total Solids	223	207	220	210	217
Total Hardness	63	72	71	69	78
Chloride	90	78	80	73	78
Conductivity (umhos/cm)	344	315	354	345	499
Ammonia Nitrogen	0.75	0.12	0.12	0.87	0.20
Nitrate Nitrogen	1.0	1.3	1.6	1.5	1.8
Nitrite Nitrogen	0.002	0.002	0.003	0.002	0.002
Total Phosphorus	0.04	0.05	0.05	0.29	0.28
Total Alkalinity	39	42	42	43	37
Total Coliform per 100 ml	1407	431	6278	14,433	14,425
Fecal Coliform per 100 ml	304	54	1182	2865	1951
Fecal Strep per 100 ml	469	507	994	767	1905

TABLE II-14

COMPARISON OF NURP AND 314 DATA
(COMMON STATIONS)
POOR FARM BROOK

Parameter*	Q10	STA 1
pH (Std. Units)	7.4	6.6
Dissolved Oxygen	9.3	9.7
Temperature °C	13.3	8.3
Total Solids	185	217
Total Hardness	65	78
Chloride	38	78
Conductivity (umhos/cm)	246	499
Ammonia Nitrogen	0.07	0.20
Nitrate Nitrogen	0.5	1.8
Total Phosphorus	0.06	0.28
Total Alkalinity	37	37
Total Coliform per 100 ml	2175	14,425
Fecal Coliform per 100 ml	163	1951
Fecal Strep per 100 ml	118	1905

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* All concentrations reported in mg/l except where noted.

Analysis of both the water quality data and watershed characteristics suggest segmenting the brook in the following manner:

Segment 1: Headwaters to Clark Street
Segment 2: Clark Street
Segment 3: Route 70 to Lake Quinsigamond

Water quality problems identified within each segment may be summarized as follows:

Segment 1: Data from STA 5, as shown in Table II-8 , indicates that Poor Farm Brook is polluted from its origin. Bacteria levels exceed the Class B criteria. Bacteria and nitrogen levels indicate a source,or sources, of dilute sewage; most probably septic systems. The oxidation of ammonia to nitrate over this segment, which continues over the length of the brook, further suggests a sewage source of pollution. High chloride levels represent a combination of sewage contamination and substantial road salt application. Data for STA 4 indicate a significant improvement in overall quality conditions which reflect changes in land use over this segment, from suburban residential, with light industry and commercial development,to agriculture (prison farm) and open space(golf course). In particular, bacteria levels at STA 4 meet the criteria for Class B water quality.

Segment 2: Water quality data at STA 3 and 2 indicate a deterioration in conditions over this reach. Bacteria, which are again in violation of Class B criteria, and solids levels increase significantly from STA 4. Bacteria levels can be attributed to both urban runoff sources and misconnections, leaks and/or overflows of the sanitary sewerage system to the stormwater systems which discharge to the brook between upper East Mountain St. - Clark St. - lower East Mountain Street. A steady increase in temperature along the length of the brook can be attributed to the absence of tree cover along the banks. Increases in solids loads may be attributed to urban runoff and urban erosion. Winter salt/sand application for snow and ice control contribute both to solids and chloride levels.

Segment 3: Water quality conditions in this reach primarily reflect the impacts of upstream pollution sources. Additional sources in this segment which do contribute to solids and chloride levels include runoff from industrial development and severe erosion problems above and below City Farm Pond. The effectiveness of City Farm Pond as a natural "instream" treatment system is reflected in the reduced levels of ammonia nitrogen and bacteria.

COAL MINE BROOK

Coal Mine Brook originates in Worcester on the grounds of the former Lincoln Country Club, now known as Lincoln Village, a dense low-to-moderate income housing development. A recently constructed shopping center resulted in the filling of the last remaining above-ground portion of this section of the brook. This relatively small drainage area is located entirely within the City of Worcester.

Emanating from its source, the Brook emerges under Lincoln Street and flows along the western end of the Lincoln Plaza Shopping Center, and under I-290. From I-290, Coal Mine flows through the Convent property owned and maintained by the Notre Dame Institute. As the Brook flows through this area, it is joined by a drainage culvert which receives drainage from Lincoln Plaza and I-290.

Before Coal Mine Brook leaves the Notre Dame property, it is joined by an intermittent stream which originates at the base of Belmont Hill along Plantation Street, draining that area and portions of Wigwam Hill. From this point, the Brook flows under Plantation Street, past the Fallon Clinic, under Lake Avenue and discharges to the Lake below a city of Worcester water supply pumping station.

The brook and its contributing drainage area are shown on Figure II-8. Tables II-15 through II-19 summarize data collected under the Upper Watershed Monitoring Program. Table II-20 summarizes the average concentrations of various

COAL MINE BROOK
SAMPLING STATIONS

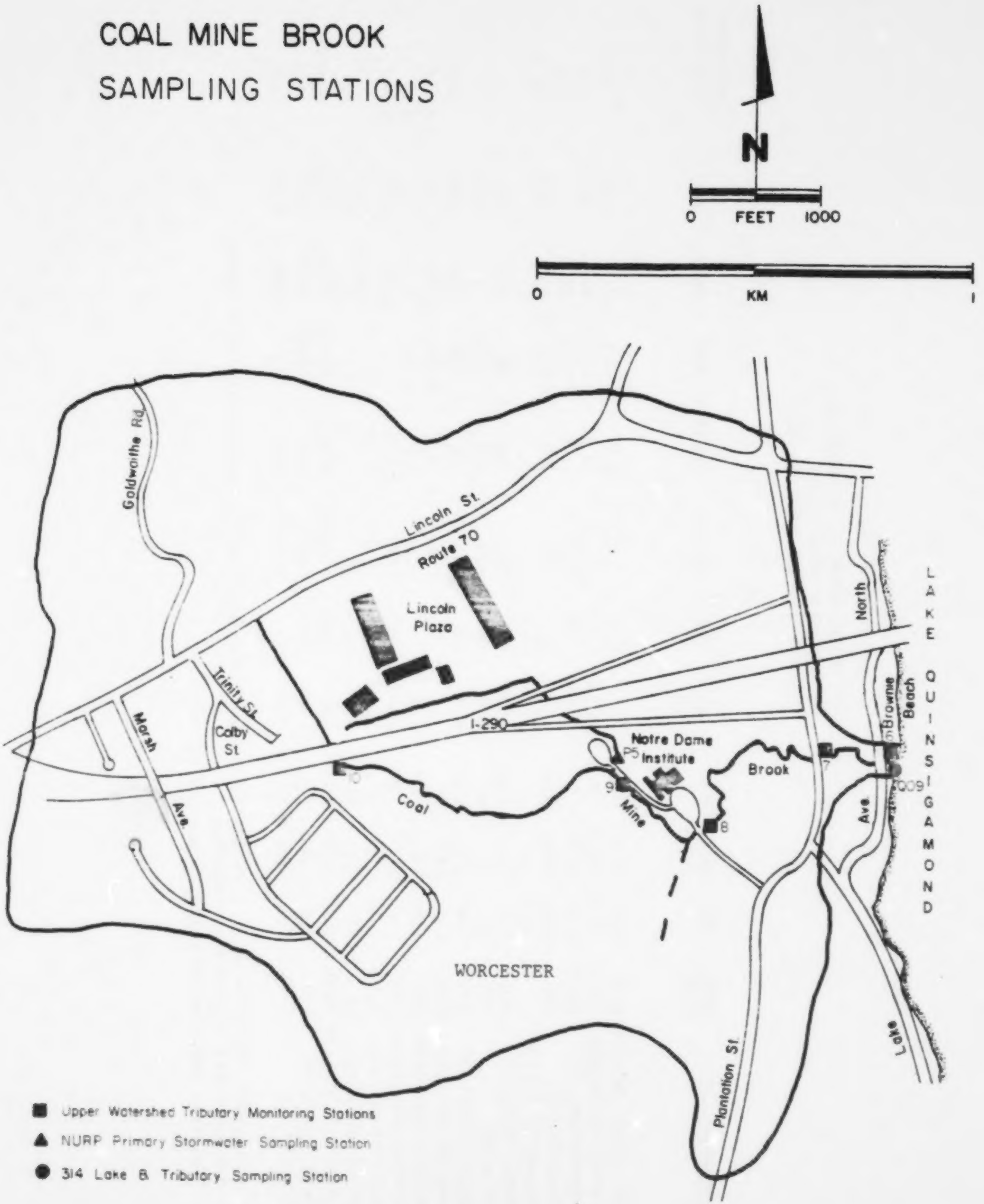
N
0 FEET 1000
0 KM 1
Goldwaithe Rd.
Lincoln St.
Route 70
Lincoln Plaza
Trinity St.
Colby St.
Marsh Ave.
I-290
Notre Dame Institute
P5
9
10
Coal
Mine
Brook
8
7
009
Browning Beach
North Ave.
LAKE QUINSIGAMOND
WORCESTER
Plantation St.
Lake
■ Upper Watershed Tributary Monitoring Stations
▲ NURP Primary Stormwater Sampling Station
● 314 Lake & Tributary Sampling Station

FIGURE II-8

TABLE II-15

COAL MINE BROOK - STATION 10
AT CULVERT BELOW I-290
WATER QUALITY DATA (mg/1)

Parameter (1)	Sept 1980	Oct	Nov	Dec	Jan 1981	Feb	March	April	May	June	Ave.	Standard Deviation
pH (Std. Units)	6.7	7.2	7.2	7.6	7.3	6.3	7.1	8.2	7.3	7.5	7.2	.5
Dissolved Oxygen	10.0	10.5	11.6	13.0	11.9	12.2	11.3	11.0	9.0	8.7	10.9	1.4
Temperature °C	15.0	8.5	4.0		0.0	5.0	5.0	11.0	16.0	19.5	9.3	6.5
Total Solids	298	242	184	310	388	346	320	300	224	450	306	78
Suspended Solids	-	13.0	-	-	-	-	-	-	-	-	-	-
Total Hardness	110	108	9	119	109	80	95	110	88	172	107	27
Chloride	165	80	84	92	243	163	127	118	120	-	132	52
Conductivity (2)	500	500	290	450	600	680	355	480	350	580	429	140
Ammonia-Nitrogen	0.10	0.32	0.12	0 .11	0 .62	0 .18	0.08	0 .07	0 .09	0.18	0 .19	0 .17
Nitrate-Nitrogen	2.6	1.9	0.9	2.1	3.0	2.5	2.6	2.0	0 .9	2.5	2.1	0 .7
Nitrite-Nitrogen	0.001	-	0.008	0.005	0.009	0.005	0.001	0.003	-	0.15	0.02	0 .05
Total Phosphorus	0.20	0.01	0.27	0.11	0.18	0.15	0.04	0.10	-	0.01	0.12	0.12
Total Alkalinity	61	52	40	58	74	63	85	51	46	71	60	14
Total Coliform (3)	7800	3400	700	18000	16000	4000	200000	3000	24000	18000	29490	60444
Fecal Coliform	850	570	1880	3400	4100	60	25000	100	3100	1100	4016	7509
Fecal Strep	1040	270	440	3500	200	90	1700	400	900	2000	1054	1055

1) All units reported as mg/1 except bacteria and conductivity or unless otherwise noted.
2) Conductivity reported as umhos/cm.
3) Bacteria reported as colonies per 100 ml.

TABLE II-16

COAL MINE BROOK - STATION 9

CONFULENCE WITH I-290/LINCOLN PLAZA DRAIN

WATER QUALITY DATA (mg/l)

Parameter (1)	Sept 1980	Oct	Nov	Dec	Jan 1981	Feb	March	April	May	June	Avg.	
pH (Std. Units)	6.7	7.2	7.1	7.5	N	7.2	7.3	7.8	7.2	7.5	7.3	0 .3
Dissolved Oxygen	9.0	11.3	11.8	13.6	O	14.0	12.5	10.7	9.0	8.4	11.1	2.0
Temperature ^{o}C	12.5	6.0	2.0		T	0	4.0	12.0	16.0	15.0	8.4	6.2
Total Solids	498	240	200	310		272	370	370	260	384	323	92
Suspended Solids	40.0	16.5	-	-	S	-	-	-	-	-	-	-
Total Hardness	160	128	82	136	A	91	120	117	96	144	119	26
Chloride	195	81	74	98	M	105	133	129	120	-	117	38
Conductivity (2)	600	550	335	480	P	400	410	520	370	480	461	86
Ammonia-Nitrogen	0.04	0 .02	0.03	0.03	L	0 .15	0 .04	0 .03	0 .06	0.07	0 .05	0 .04
Nitrate-Nitrogen	1.8	1.9	1.0	1.9	E	2.1	2.3	1.9	0 .9	1.9	1.7	0 .47
Nitrite-Nitrogen	0.001	-	0.004	0.003	D	0.003	0.001	0.001	-	0.001	0.002	0 .001
Total Phosphorus	0.10	0.06	0.11	0.09		0.15	0.04	0.05	-	0.05	0.08	0.04
Total Alkalinity	86	67	48	65		41	107	55	47	58	64	21
Total Coliform (3)	400	400	800	800		400	2700	500	4500	6800	1992	2306
Fecal Coliform	20	10	410	10		120	130	<10	790	170	186	261
Fecal Strep	70	30	130	-		20	20	40	570	1100	248	391

1) All units reported as mg/l except bacteria and conductivity or unless otherwise noted.
2) Conductivity reported as umhos/cm.
3) Bacteria reported as colonies per 100 ml.

TABLE II-17

COAL MINE BROOK - STATION 8
BELOW CULVERT AT NOTRE DAME
WATER QUALITY DATA (mg/1)

Parameter (1)	Sept 1980	Oct	Nov	Dec	Jan 1981	Feb	March	April	May	June	Avg.	S.D.
pH (Std. Units)	6.2	6.9	7.1	7.3	6.9	7.2	6.9	7.5	7.2	7.4	7.1	0 .4
Dissolved Oxygen	6.4	10.4	12.2	13.5	12.7	13.7	12.7	11.2	8.8	8.2	10.0	2.7
Temperature °C	13.0	7.5	2.0	-	0	1.0	3.0	10.0	15.0	18.0	7.7	6.2
Total Solids	290	196	292	269	246	308	246	300	230	340	262	44
Suspended Solids	19.1	14.0	-	-	-	-	-	-	-	-	-	-
Total Hardness	68	111	81	113	106	81	82	94	72	108	92	17
Chloride	85	80	81	101	153	98	95	101	99	-	99	30
Conductivity (2)	200	500	325	430	385	480	250	410	240	370	359	91
Ammonia- Nitrogen	0.03	0.01	0.02	0.02	0.30	0.16	0.03	0.03	0.03	0.05	0.07	0.09
Nitrate-Nitrogen	0.9	1.4	0.9	1.7	2.1	2.1	1.6	1.5	0.8	1.3	1.4	0 .47
Nitrite-Nitrogen	0.000	-	0.003	0.003	0.001	0.002	0.001	0.001	-	0.001	0.002	0 .001
Total Phosphorus	0.04	0.03	0.02	0.04	0.16	0.75	0.04	0.06	-	0.01	0.13	0.24
Total Alkalinity	28	54	42	52	42	52	54	35	37	45	44	9
Total Coliform (3)	1300	900	2200	100	<100	140	450	40	1000	2500	873	895
Fecal Coliform	220	90	210	10	50	50	20	<10	530	150	134	160
Fecal Strep	170	90	180	<10	10	20	<10	50	440	6500	748	2,025

1) All units reported as mg/l except bacteria and conductivity or unless otherwise noted.
2) Conductivity reported as umhos/cm.
3) Bacteria reported as colonies per 100 ml.

TABLE II-18

COAL MINE BROOK - STATION 7

PLANTATION STREET
WATER QUALITY DATA (mg/l)

Parameter (1)	Sept 1980	Oct	Nov	Dec	Jan 1981	Feb	March	April	May	June	Avg.	Standard Deviation
pH (Std. Units)	6.5	7.3	7.2	7.5	7.2	7.3	7.3	8.0	7.2	7.4	7.3	0.4
Dissolved Oxygen	7.4	10	12.9	13.8	13.5	13.9	13.4	11.1	9.8	9.4	11.7	2.0
Temperature °C	16.0	10.0	4.0	-	2.0	1.0	3.0	11.0	16.0	16.0	9.0	6.0
Total Solids	271	140	246	328	260	290	290	270	180	288	256	56
Suspended Solids	18.1	10.0	-	-	-	-	-	-	-	-	-	-
Total Hardness	55	81	76	110	89	89	90	94	84	92	86	14
Chloride	79	65	88	123	149	110	93	100	98	-	101	25
Conductivity (2)	250	450	380	550	360	550	315	390	250	360	386	106
Ammonia-Nitrogen	0.05	0.16	0.02	0.04	0.22	0.25	0.03	0.03	0.04	0.04	0.09	0.09
Nitrate-Nitrogen	1.4	1.4	1.0	0.9	1.8	2.1	1.8	1.4	0.8	1.4	1.4	0.59
Nitrite-Nitrogen	0.003	-	0.002	0.002	0.002	0.002	<.001	0.001	-	0.001	0.002	0.001
Total Phosphorus	0.12	0.06	0.04	0.04	0.16	0.16	0.00	0.06	-	0.08	0.08	0.06
Total Alkalinity	31	41	44	49	39	52	73	36	37	55	46	12
Total Coliform (3)	8500	28000	23000	13000	52000	28000	22000	4000	13000	85000	27650	24247
Fecal Coliform	2810	4500	2600	1400	10500	5700	3800	1300	2700	9100	5611	3371
Fecal Strep	1350	2640	6800	<100	910	620	500	300	1700	4000	1892	2130

1) All units reported as mg/l except bacteria and conductivity or unless otherwise noted.
2) Conductivity reported as umhos/cm.
3) Bacteria reported as colonies per 100 ml.

TABLE II-19

COAL MINE BROOK - STATION 6

LAKE AVENUE AT GAGE
WATER QUALITY DATA (mg/1)

Parameter (1)	Sept 1980	Oct	Nov	Dec	Jan 1981	Feb	March	April	May	June	Avg.	S.D.
pH (Std. Units)	6.4	7.2	7.2	7.7	N	7.5	7.2	7.5	7.4	7.3	7.3	0.4
Dissolved Oxygen	9.0	11.6	11.8	13.8	O	14.2	13.4	11.0	9.6	9.3	11.5	2.0
Temperature °C	13	8.5	3	-	T	1	3	11	16	17	9.1	6.2
Total Solids	319	224	280	300		272	240	260	160	318	264	51
Suspended Solids	17.1	12.5	-	-	S	-	-	-	-	-	-	-
Total Hardness	56	78	78	99	A	81	92	98	80	96	84	14
Chloride	77	66	76	121	M	112	98	-	96	-	92	20
Conductivity (2)	300	450	980	545	P	525	320	400	140	350	456	249
Ammonia-Nitrogen	0.02	0.10	0.03	0.04	L	0.17	0.03	0.04	0.08	0.05	0.06	0.03
Nitrate-Nitrogen	1.2	1.5	1.1	1.7	E	2.2	1.7	1.5	0.8	1.4	1.5	0.4
Nitrite-Nitrogen	0.002	-	0.002	0.003	D	0.002	0.001	0.001	-	0.001	0.002	0.001
Total Phosphorus	0.16	0.03	0.81	0.04		0.01	0.09	0.10	-	0.05	0.16	0.27
Total Alkalinity	33	36	40	49		36	90	42	33	40	44	18
Total Coliform (3)	6300	5100	4700	3100		9400	16000	9000	11000	100000	18289	30782
Fecal Coliform	1930	2010	920	400		3800	3400	4900	1900	11000	3362	3195
Fecal Strep	1070	470	3840	100		580	<100	600	600	5000	1373	1775

1) All units reported as mg/1 except bacteria and conductivity or unless otherwise noted.
2) Conductivity reported as umhos/cm.
3) Bacteria reported as colonies per 100 ml.

TABLE II-20

AVERAGE DATA VALUES (mg/1)

COAL MINE BROOK

Parameter	STA 10	STA 9	STA 8	STA 7	STA 6
pH (Std. Units)	7.2	7.3	7.1	7.3	7.3
Dissolved Oxygen	10.9	11.1	10.0	11.7	11.5
Temperature °C	9.3	8.4	7.7	9.0	9.1
Total Solids	306	323	262	256	264
Total Hardness	107	119	92	86	84
Chloride	132	117	99	101	92
Conductivity (umhos/cm)	479	461	359	386	456
Ammonia Nitrogen	0.19	0.05	0.07	0.09	0.06
Nitrate Nitrogen	2.1	1.7	1.4	1.4	1.5
Nitrite Nitrogen	0.002	0.002	0.002	0.002	0.002
Total Phosphorus	0.12	0.08	0.13	0.08	0.16
Total Alkalinity	60	64	44	46	44
Total Coliform per 100 ml	29,490	1992	873	27,650	18,289
Fecal Coliform per 100 ml	4016	185	134	5611	3362
Fecal Strep per 100 ml	1054	248	748	1892	1373

TABLE II-21

COMPARISON OF NURP AND 314 DATA
(COMMON STATIONS)
COAL MINE BROOK

Parameter *		Q09	STA 6
pH (std. units)		7.6	7.3
Dissolved Oxygen		10.6	11.5
Temperature °C		12.4	9.1
Total Solids		223	264
Total Hardness		84	84
Chloride		62	92
Conductivity (umhos/cm)		329	456
Ammonia Nitrogen		0.05	0.06
Nitrate Nitrogen		0.8	1.5
Total Phosphorus		0.08	0.16
Total Alkalinity		37	44
Total Coliform	per 100 ml	14,733	18,289
Fecal Coliform	per 100 ml	1305	3362
Fecal Strep	per 100 ml	278	1373

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* All concentrations reported in mg/l except where noted.

parameters observed over the sampling period. Table II-21 shows a comparison between STA 6 and Q09 which represents the same sampling station as sampled under the two sampling programs as previously described.

Land use in the watershed ranges from intense urban residential and commercial development in the upper reaches, to open space in the middle reaches, to commercial and urban/transportation uses in the lower reaches, to the brook's confluence with the lake. Consistent with the water quality data and the pattern of land use in the watershed, the brook may be segmented as follows:

Segment 1: Source to Lincoln Plaza Drain
Segment 2: Lincoln Plaza Drain to Plantation St.
Segment 3: Plantation St. to Lake Quinsigamond

Water quality conditions observed within each segment are discussed below.

Segment 1: As indicated by the data for STA 10, this segment is polluted. In addition to bacteria levels which exceed the Class B water quality criteria, high levels of solids, chloride , conductivity, nitrogen and phosphorus are observed at this station. This data suggests a sewage source of contamination in addition to the urban runoff and substantial road salt/sand runoff.

Segment 2: Data for stations 9 and 8 indicate a significant improvement from the upstream reach of the brook. Class B bacteria criteria are met over the entire reach. Significant reductions in nitrogen and phosphorus are observed. Chloride levels, although slightly reduced, are still high. An observed increase in solids at STA 9 can be attributed to highway runoff from I-290 and soil erosion from the embankment at the rear of the Lincoln Plaza shopping center.

Segment 3: Bacteria levels in this segment increase significantly over the previous segment, approaching the levels observed in Segment 1, which again violate the Class B water quality criteria. The source of the problem has been traced to a storm drain which originates on Lincoln Street and discharges to the brook at the bridge abutment at Plantation Street. Misconnections, leaks and broken sections of pipe have been identified in this line. A program to identify and correct problems as they are found has been undertaken by the City Health Department in cooperation with the Public Works Department. The presence and magnitude of the bacteria problem in this segment is directly responsible for the closing of the municipal water supply pumping station located near the mouth of the brook. Re-opening this well for use is dependent on the solution to this particular problem. Comparison of data at Q09 and STA 6(same station) as shown in Table II-21 indicate that overall pollution levels are higher during wet periods.

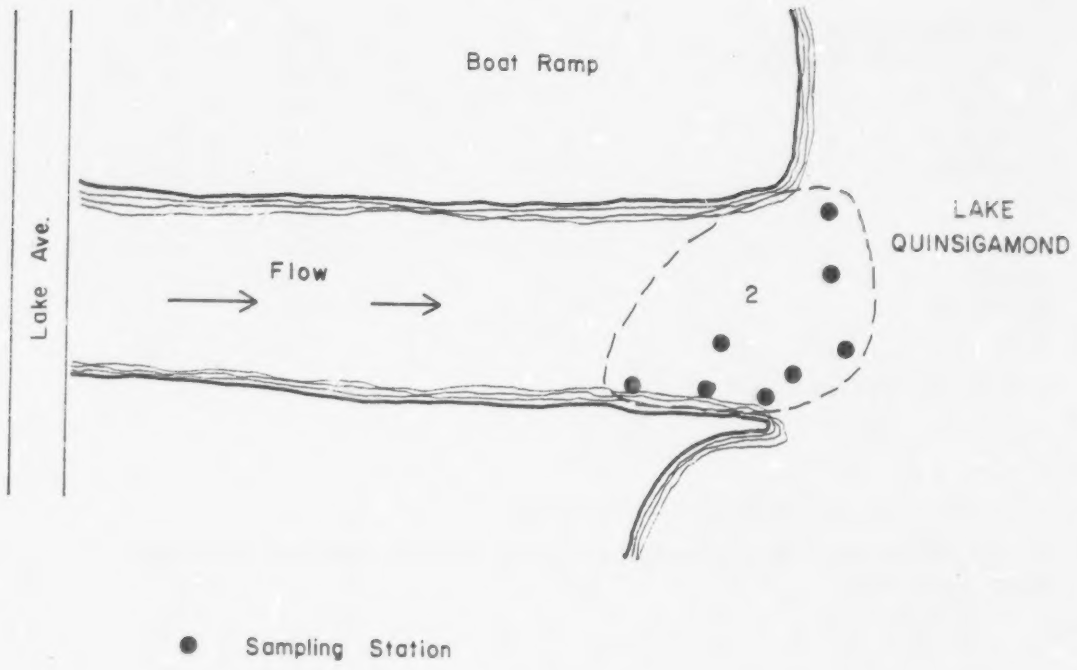
A composite sediment sample was collected at the mouth of the brook as shown in Figure II-9. The data, shown in Table II-22 indicate relatively high phosphorus levels. Levels of aluminium, arsenic, lead, nickel and zinc are also fairly high indicating transportation and erosion as probable sources. The Sediment Pollution Index computed for this site of 4.2 is slightly higher than Fitzgerald Brook and the Medical School Drain and is indicative of a slight degree of sediment pollution.

Medical School Drain

The Medical School Drain (AKA:Big Ugly Pipe) includes the drainage system for the UMASS Medical School and Hospital complex plus a natural brook system draining a major portion of Belmont Hill including the State Hospital site. The brook originates under Plantation Street and runs between Mohican Road and the North Access Road to the Medical School. As shown in Figure II-10, the brook joins the medical school drainage system at the North Access Road and is culverted to the Lake via a 54" drain. A landfill on the State Hospital property is located within this drainage area.

Monitoring of the brook indicates that, during dry weather periods, the water quality of the brook is very good. However, the accumulation of

COAL MINE BROOK
SEDIMENT SAMPLING STATIONS


Boat Ramp
Lake Ave.
Flow
2
LAKE
QUINSIGAMOND
● Sampling Station

(DRAWING NOT TO SCALE)

FIGURE II-9

TABLE II-22

COAL MINE BROOK
SEDIMENT DATA

Parameter	Concentration *
Total Phosphorus	2300
Total Kjeldahl Nitrogen	1725
Aluminum	7420
Arsenic	27
Cadmium	0.00
Chromium	33
Copper	35
Iron	17800
Lead	126
Nickel	43
Pottasium	1518
Zinc	173
Sediment Pollution Index (SPI)	4.2

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* All concentrations in dry weights (mg/kg) except Sediment Pollution Index (unitless)

MEDICAL SCHOOL DRAIN
SAMPLING STATION

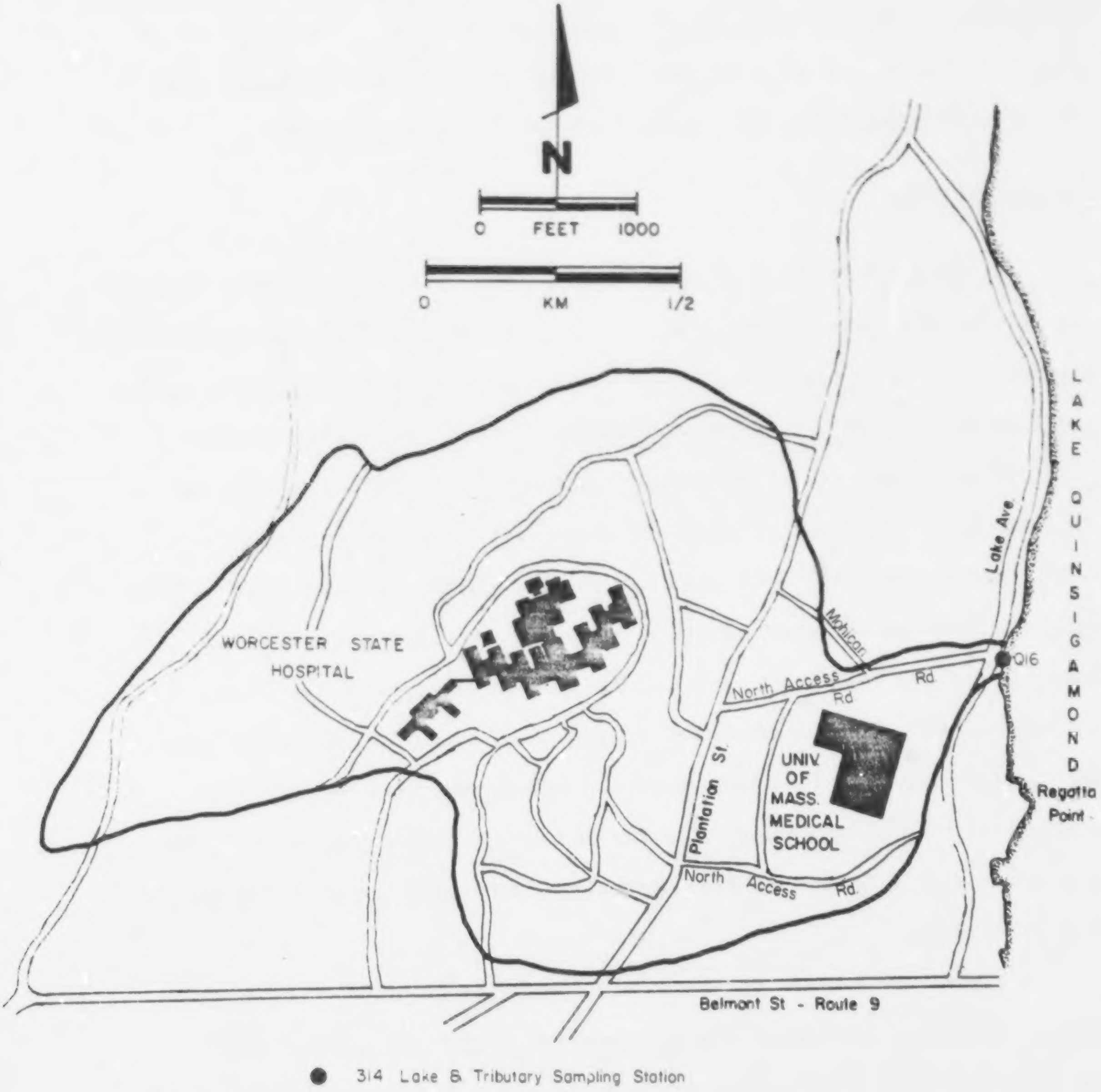

N
0 FEET 1000
0 KM 1/2
WORCESTER STATE HOSPITAL
Mohican
Lake Ave.
Q16
LAKE QUINSIGAMOND
North Access Rd
Plantation St.
UNIV. OF MASS. MEDICAL SCHOOL
Regatta Point
North Access Rd.
Belmont St - Route 9
● 314 Lake & Tributary Sampling Station

FIGURE II-10

grit and other matter indicates that storm runoff solids are a problem. This is supported by sediment sampling of the sand bar immediately below the drain outfall to the Lake (see Figure II-11). In addition to solids, the sediment sampling data indicate that heavy metals, particularly lead and zinc, are also contributed via runoff (see Table II-23).

Although this site had been selected for stormwater sampling, it had to be eliminated due to problems with access and flow gaging.

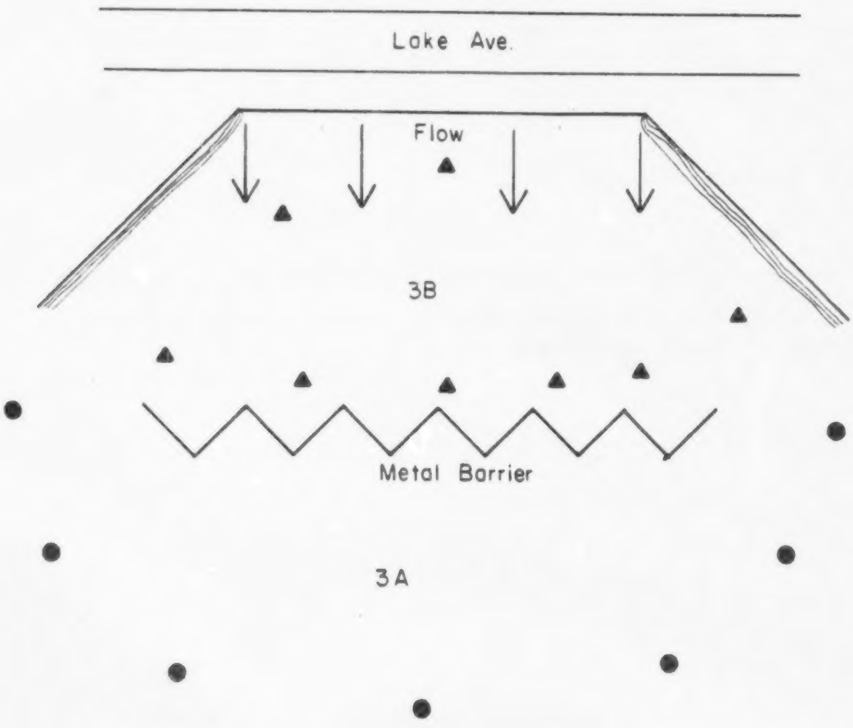
FITZGERALD BROOK

Fitzgerald Brook, as shown in Figure II-12, is located entirely within the City of Worcester, discharging to Lake Quinsigamond under Lake Avenue, about one-half mile south of Route 9. The brook drains an area of 601 acres which includes portions of Harrington Way, Hamilton Street and Grafton Street (Route 122). The natural channel of the Brook is an intermittant stream originating in the vicinity of Harold Street and Commonwealth Avenue. At Coburn Avenue, the Brook is joined by a large culvert originating in a small wetland off Cohasset Street carrying both runoff and base flow from the Hamilton and Grafton Street area. From Coburn Avenue, the Brook flows through a steep-sided rocky channel to its confluence with the Lake. Land use in the drainage area is predominantly single and multi-family residential of medium density. The Harrington Way Junior High School, the Worcester Science Center and Penn Central railroad line are also features of this watershed.

Figure II-12 shows the location of sampling stations on Fitzgerald Brook. In addition to those stations shown in Figure II-12, STA 11(Q08) was also a primary stormwater sampling site (P4). Figure II-13 is an enlargement of the mouth of the brook showing the location of sediment sampling stations. Water quality data from the upper watershed sampling program is summarized in Tables II-24 and II-25. Average parameter concentrations

MEDICAL SCHOOL DRAIN
SEDIMENT SAMPLING STATIONS

N--
(DRAWING NOT TO SCALE)


Lake Ave.
Flow
3B
Metal Barrier
3A

● Sampling Station 3A
▲ Sampling Station 3B

FIGURE II-11

TABLE II-23

MEDICAL SCHOOL DRAIN
SEDIMENT DATA

Parameter *	Stations 3B	 3A
Total Phosphorus	325	250
Total Kjeldahl Nitrogen	2825	2675
Aluminum	3740	1900
Arsenic	5.2	4.5
Cadmium	0.00	0.00
Chromium	10	10
Copper	22	19
Iron	13800	11400
Lead	66	119
Nickel	24	10
Pottasium	646	536
Zinc	61	54
Sediment Pollution Index (SPI)	1.4	1.9

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* All concentrations in dry weights (mg/kg) except Sediment Pollution Index (unitless)

FITZGERALD BROOK SAMPLING STATIONS

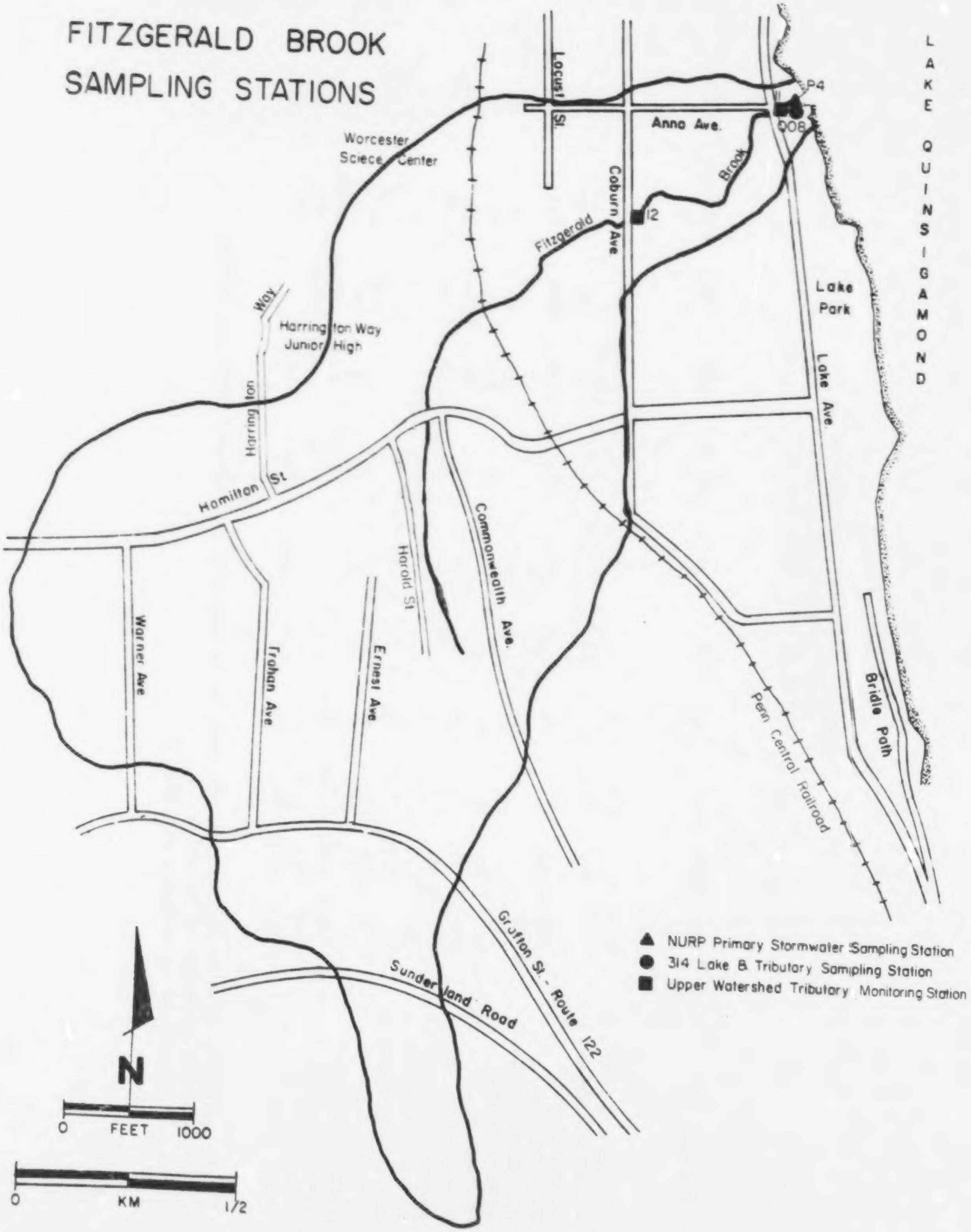
Locust St.
Anna Ave.
P4
008
Worcester Sciece Center
Coburn Ave.
12
Fitzgerald
Brook
Way
Harrington Way Junior High
Harrington
Hamilton St
Harold St
Commonwealth Ave.
Lake Park
Lake Ave.
L A K E Q U I N S I G A M O N D
Warner Ave
Trahan Ave
Ernest Ave
Penn Central Railroad
Bridle Path
Grafton St. - Route 122
Sunderland Road
N
0 FEET 1000
0 KM 1/2
▲ NURP Primary Stormwater Sampling Station
● 314 Lake & Tributary Sampling Station
■ Upper Watershed Tributary Monitoring Station

FIGURE II-12

47

TABLE II-24

FITZGERALD BROOK - STATION 11
AT STAFF GAGE ON LAKE AVENUE
WATER QUALITY DATA (mg/1)

Parameter (1)	Sept 1980	Oct	Nov	Dec	Jan 1981	Feb	March	April	May	June	Avg.	S.D.
pH (std. units)	N	7.1	7.2	7.3	7.0	7.3	7.1	6.4	7.1	7.4	7.1	0.3
Dissolved Oxygen	O	11.5	11.3	13.0	11.5	13.8	13.2	11.1	9.5	9.7	11.6	1.5
Temperature °C	T	7.5	5		0.5	8	4	10	14	14	7.9	4.7
Total Solids		197	286	152	120	236	218	230	130	260	203	58
Suspended Solids	S	8.0	-	-	-	-	-	-	-	-	-	-
Total Hardness	A	79	76	49	36	81	72	75	60	92	69	18
Chloride	M	64	92	97	89	69	75	74	81	-	80	14
Conductivity (2)	P	450	430	220	150	335	230	310	210	600	326	136
Ammonia-Nitrogen	L	0.02	0.04	0.04	0.09	0.14	0.04	0.08	0.08	0.06	0.07	0.04
Nitrate-Nitrogen	E	2.3	1.5	1.6	1.1	2.6	2.6	2.2	0.9	2.2	1.9	0.6
Nitrite- Nitrogen	D	-	0.001	0.003	0.001	0.001	0.001	0.001	-	0.02	0.004	0.007
Total Phosphorus		0.02	0.06	0.09	0.11	0.07	0.04	0.05	-	0.001	0.06	0.04
Total Alkalinity		25	36	18	12	42	39	22	31	29	28.2	9.9
Total Coliform(3)		1700	3900	13000	6000	22000	-	25000	21000	21000	14200	9266
Fecal Coliform		490	860	1780	200	8800		18000	17000	1000	6016	7016
Fecal Strep		60	2290	100	40	400	200	700	3800	-	949	1373

1) All units reported as mg/l except bacteria and conductivity or unless otherwise noted.
2) Conductivity reported as umhos/cm.
3) Bacteria reported as colonies per 100 ml.

TABLE II-25

FITZGERALD BROOK - STATION 12
BELOW COBURN AVENUE
WATER QUALITY DATA (mg/1)

Parameter (1)	Sept 1980	Oct	Nov	Dec	Jan 1981	Feb	March	April	May	June	Avg.	S.D.
pH (standard Units)	6.3	6.4	6.6	6.7	6.4	6.6	6.5	6.5	6.5	6.7	6.5	0 .1
Dissolved Oxygen	8.8	9.4	9.7	11.4	12.7	10.9	11.5	10.8	9.2	9.5	10.4	1.3
Temperature ^{o}C	15	10.5	7	-	2	5	5	10.5	13.5	14	9.2	4.6
Total Solids	298	212	274	200	98	234	182	190	150	270	211	61
Suspended Solids	18.7	7.5	-	-	-	-	-	-	-	-	-	-
Total Hardness	78	81	71	52	28	76	81	74	64	92	70	18
Chloride	135	60	92	98	73	60	73	76	80	-	83	23
Conductivity (2)	450	450	865	320	120	335	215	300	200	310	357	207
Ammonia-Nitrogen	0.21	0.05	0.02	0.08	0.06	0 .31	0 .05	0.14	0 .05	0 .04	0.10	0 .09
Nitrate-Nitrogen	3.0	2.4	1.7	1.5	0.8	2.7	2.6	2.4	1.2	2.5	2.1	0 .7
Nitrite-Nitrogen	0.006	-	0.002	0.003	0.001	0.002	<.001	0.001	-	0.007	0.003	0.001
Total Phosphorus	.24	.05	.09	.06	.10	.16	.18	.02	-	.01	.10	.08
Total Alkalinity	28	26	30	18	8	55	42	24	25	28	28	13
Total Coliform (2)	15800	21000	34000	22000	5000	32000	14000	12000	42000	19000	21630	11306
Fecal Coliform	4500	2400	11000	5400	2400	10500	8000	6000	19000	10000	7920	5010
Fecal Strep	7250	2380	3800	1900	<100	30	2200	1600	6300	7500	3306	2795

1) All units reported as mg/1 except bacteria and conductivity or unless otherwise noted.
2) Conductivity reported as umhos/cm.
3) Bacteria reported as colonies per 100 ml.

TABLE II-26

AVERAGE DATA VALUES (mg/l)
FITZGERALD BROOK

Parameter	STA 12	STA 11
pH (Standard units)	6.5	7.1
Dissolved Oxygen	10.4	11.6
Temperature	9.2	7.9
Total Solids	211	203
Total Hardness	70	69
Chloride	83	80
Conductivity (umhos/cm	357	326
Ammonia Nitrogen	0.10	0.07
Nitrate Nitrogen	2.1	1.9
Nitrite Nitrogen	0.003	0.004
Total Phosphorus	0.10	0.06
Total Alkalinity	28	28
Total Coliform per 100 ml	21,630	14,200
Fecal Coliform per 100 ml	7920	6016
Fecal Strep per 100 ml	3306	949

TABLE II-27

COMPARISON OF NURP AND 314 DATA
(COMMON STATIONS)
FITZGERALD BROOK

Parameter *	Q08	STA 11
pH (Standard Units)	7.4	7.1
Dissolved Oxygen	10.3	11.6
Temperature °C	12.0	7.9
Total Solids	206	203
Total Hardness	72	69
Chloride	51	80
Conductivity (umhos/cm)	301	326
Ammonia Nitrogen	0.07	0.07
Nitrate Nitrogen	1.3	1.9
Total Phosphorus	0.08	0.06
Total Alkalinity	26	28
Total Coliform Per 100 ml	8305	14,200
Fecal Coliform Per 100 ml	952	6016
Fecal Strep Per 100 ml	227	949

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* All concentrations reported in mg/l except where noted.

FITZGERALD BROOK OUTLET SEDIMENT SAMPLING STATIONS

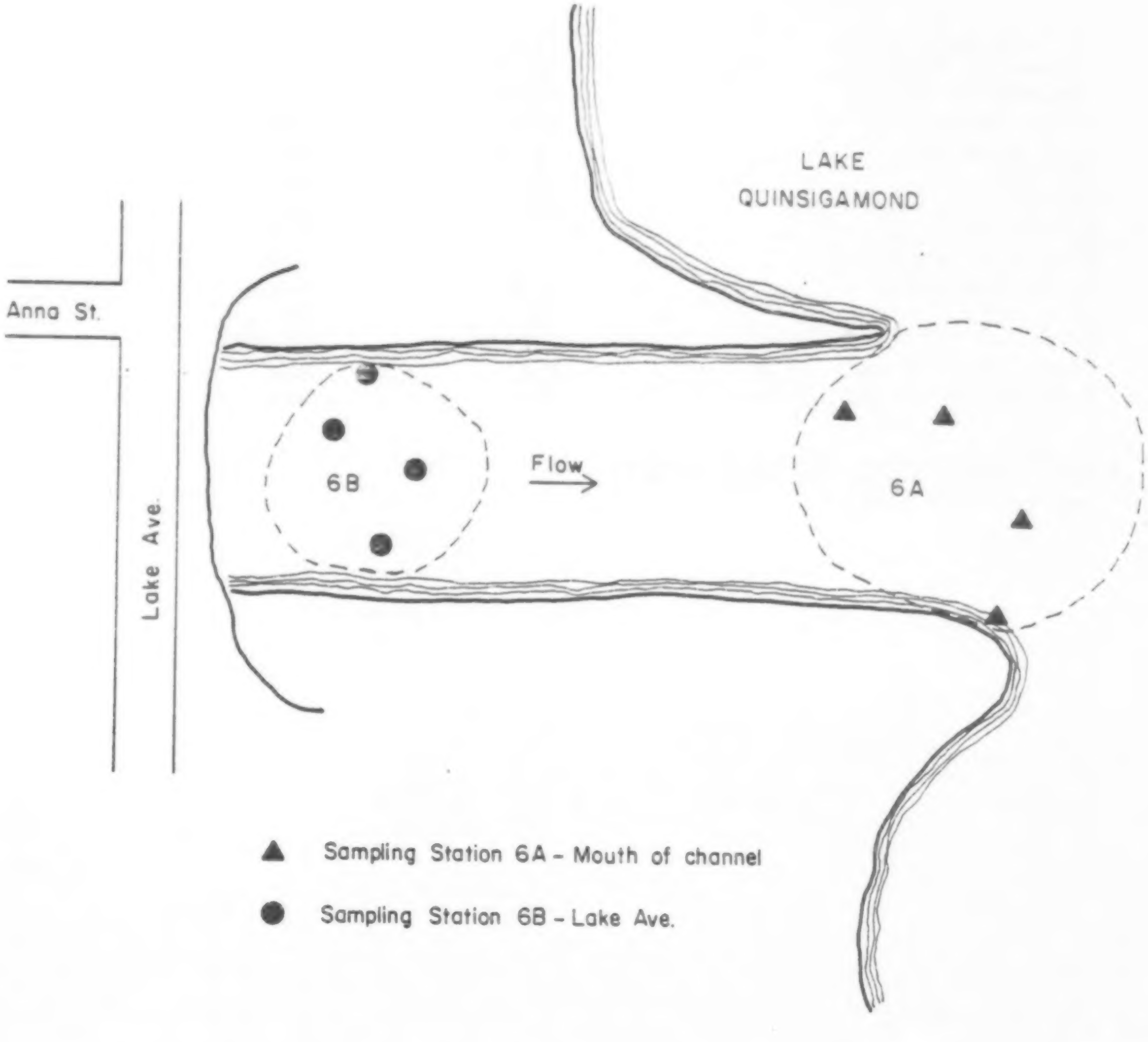
LAKE QUINSIGAMOND
Anna St.
Lake Ave.
6B
Flow
6A
▲ Sampling Station 6A - Mouth of channel
● Sampling Station 6B - Lake Ave.

FIGURE II-13

TABLE II-28

FITZGERALD BROOK
SEDIMENT DATA

Parameter*	Stations	
Station	6B	6A
Total Phosphorus	750	350
Total Kjeldahl Nitrogen	2700	2575
Aluminum	38800	3665
Arsenic	16	4.8
Cadmium	0.00	0.00
Chromium	12	10
Copper	25	-
Iron	11663	15660
Lead	131	87
Nickel	8.9	10
Pottasium	745	766
Zinc	89	80
Sediment Pollution Index (SPI)	3.1	1.6

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* All concentrations in dry weights (mg/kg) except Sediment Pollution Index (unitless)

observed at stations 12 and 11 are presented in Table II-26.

Analysis of the available data reveals that the brook is generally in violation of the Class B water quality criteria for bacteria. Chloride and nutrient levels are also fairly high. As shown in Table II-27, with the exception of chloride and bacteria levels, there does not appear to be a significant seasonal variation as has been observed at other tributaries. The sampling data, combined with further investigation by the City Health Department, indicate that misconnections and broken/leaky sewer pipes are the major sources of bacterial pollution. As discussed further in the section on stormwater sampling, runoff data at station P4 indicate a well-defined "first flush" effect for solids, nitrogen, particulate phosphorus and chemical oxygen demand. Due to the relative consistency of land use and water quality data between stations, it is not necessary to segment the watershed.

Sediment samples were collected at two locations near the mouth of the brook as shown in Figure II-13. The data is summarized in Table II-28. As indicated by the sediment pollution index calculated for each station, an improvement generally takes place between station 6B and 6A. This can be attributed to solids settling as suggested by the decreases in arsenic, copper, lead and zinc. The data suggest a transportation related source of runoff.

O'HARA BROOK

As shown in Figure II-14, O'Hara Brook lies entirely within the City of Worcester. The brook originates in the vicinity of Jennings and Grafton Streets. From its source, the brook flows south parallel to Grafton Street. Before crossing under Sunderland Road, the brook is joined by a small branching tributary which originates in a wetland in the Blithewood Avenue area. The brook turns east under Crane Street and the railroad tracks and then

O'HARA BROOK SAMPLING STATIONS

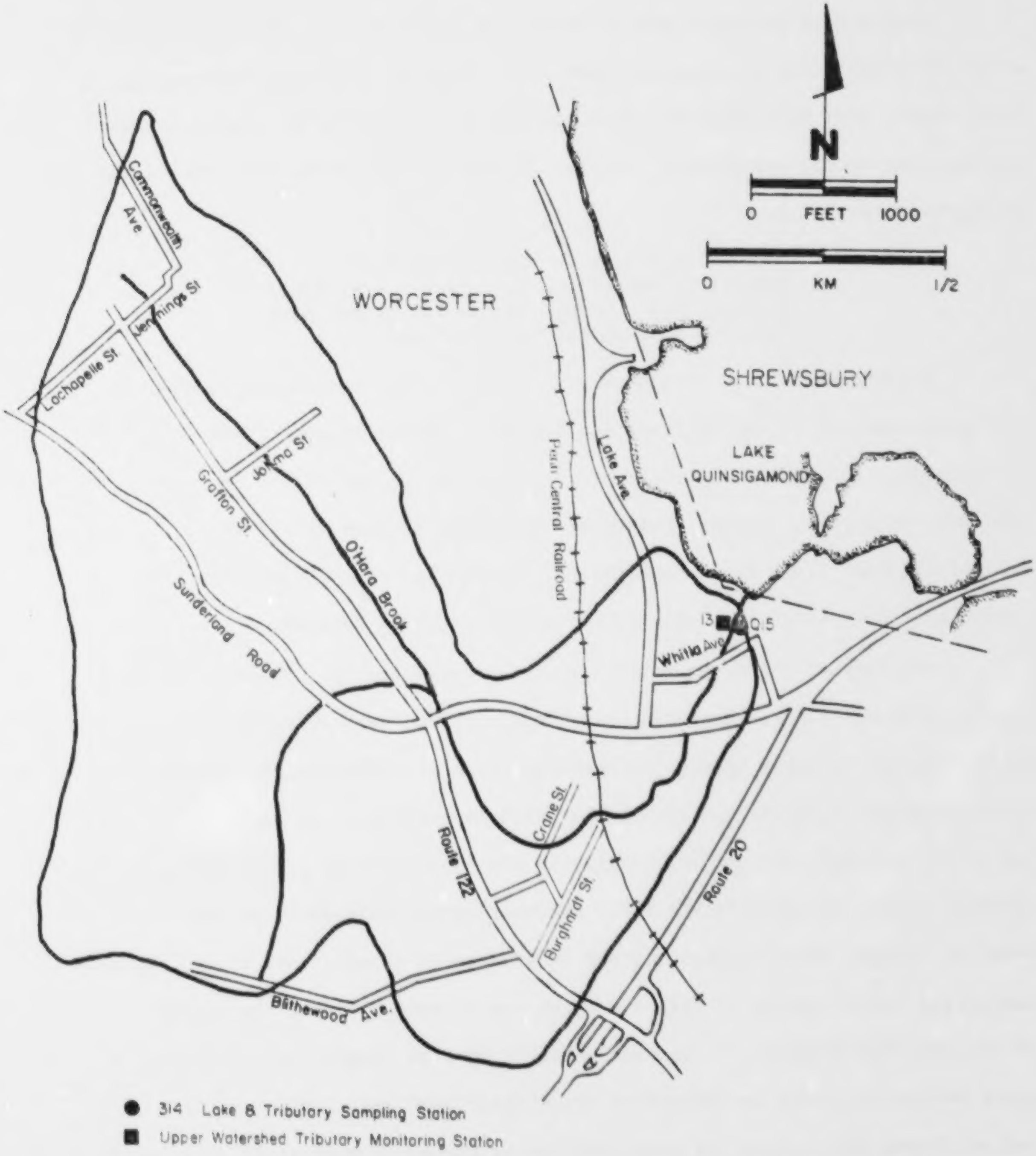
N
0 FEET 1000
0 KM 1/2
WORCESTER
SHREWSBURY
LAKE QUINSIGAMOND
Commonwealth Ave
Jennings St
Lachapelle St
Johnma St
Grafton St
Sunderland Road
O'Hara Brook
Penn Central Railroad
Lake Ave.
13
0.5
Whitla Ave.
Crane St.
Route 122
Burghardt St
Route 20
Blithewood Ave.
● 314 Lake & Tributary Sampling Station
■ Upper Watershed Tributary Monitoring Station

FIGURE II-14

turns north as it approaches Sunderland Road for the second time. From Sunderland Road to Whitla Avenue, the brook flows through an enclosed concrete conduit. The brook emerges behind 17 Whitla Avenue and enters the southern end of Lake Quinsigamond.

Land use in the watershed is primarily medium density residential with some commercial establishments and open land. Several apartment and condominium developments have been constructed in the Sunderland Road area. Based on land use characteristics and physical changes in the drainage area, the O'Hara brook can be segmented as follows:

Segment 1: Source to Sunderland Road
Segment 2: Sunderland Road to B & M Railroad
Segment 3: B & M Railroad to Sunderland Road
Segment 4: Sunderland Road to Lake

Water quality data is limited to a single sampling station located at the downstream end of the enclosed conduit below Whitla Avenue. This station was included in both the 314 (Q15) and Upper Watershed Monitoring Programs (STA 13). Data from the Upper Watershed Monitoring Program is presented in Table II-29. Table II-30 compares the average concentrations of various parameters observed at this station under both sampling programs.

Analysis of the water quality data indicates that the brook is fairly clean. (Although average bacteria data violate the Class B criteria, the monthly monitoring data indicate violations occur sporadically with several consecutive sampling dates on which the criteria were met.) As shown on Table II-30, solids, chloride, conductivity and nitrogen show a substantial increase during wet periods(STA 13). Bacteria levels decrease over the sampling periods which suggests either an isolated misconnection, an occasionally discharged septic system or that a problem was corrected during the course of the sampling program. It is also possible that an unmeasured constituent might be present which is inhibiting to coliform bacteria. Urban runoff and salt/sand application are considered to be the major sources of pollutants in this watershed.

TABLE 11-29

O'HARA BROOK - STATION 13
AT STAFF GAGE ON CULVERT BEHIND 17 WHITLA DRIVE
WATER QUALITY DATA (mg/l)

Parameter(1)	Sept 1980	Oct	Nov	Dec	Jan 1981	Feb	March	April	May	June	Avg.	S.D.
pH (Standard units)	N	N	6.8	7.0	N	6.9	6.1	7.0	6.6	6.6	6.7	0.3
Dissolved Oxygen	O	O	12.7	13.7	O	14.3	12.8	11.0	9.1	8.7	11.8	2.2
Temperature °C	T	T	3	-	T	1	5	11	16	-	7.2	6.2
Total Solids			372	396		240	216	210	152	240	261	89
Suspended Solids	S	S	-	-	S	-	-	-	-	-	-	-
Total Hardness	A	A	83	98	A	82	58	53	56	84	73	18
Chloride	M	M	350	335	M	66	70	54	-	-	175	-
Conductivity (2)	P	P	610	580	P	470	235	350	210	330	398	159
Ammonia-Nitrogen	L	L	0.03	0.08	L	0.25	0.05	0.08	0.11	0.05	0.09	0.07
Nitrate-Nitrogen	E	E	1.3	1.9	E	2.4	2.2	1.9	0.9	1.3	1.7	0.53
Nitrite-Nitrogen	D	D	0.002	0.003	D	0.001	0.001	0.001	-	0.001	0.002	0.001
Total Phosphorus			0.06	0.06		0.03	0.00	0.02	-	0.001	0.03	0.03
Total Alkalinity			24	32		30	45	29	28	44	33	8
Total Coliform (3)			900	1100		<100	2500	200	2900	8500	2327	2930
Fecal Coliform			260	10		40	120	10	770	720	276	332
Fecal Strep			210	-		40	10	50	1180	2600	682	1040

1) All units reported as mg/l except bacteria and conductivity or unless otherwise noted.
2) Conductivity reported as umhos/cm.
3) Bacteria reported as colonies per 100 ml.

TABLE II-30

COMPARISON OF NURP AND 314 DATA
(COMMON STATIONS)
O'HARA BROOK

Parameter *	Q15	STA 13
pH (Standard Units)	7.3	6.7
Dissolved Oxygen	9.9	11.8
Temperature(°C)	12.2	7.2
Total Solids	164	261
Total Hardness	60	73
Chloride	47.4	175
Conductivity (umhos/cm)	269	398
Ammonia Nitrogen	0.05	0.09
Nitrate Nitrogen	0.67	1.7
Total P	0.07	0.03
Total Alkalinity	30.0	33.0
Total Coliform per 100 ml	8849	2327
Fecal Coliform per 100 ml	582	276
Fecal Strep per 100 ml	266	682

---

*All concentrations reported in mg/l except where noted.

SOUTH MEADOW BROOK

South Meadow Brook is located entirely within the Town of Shrewsbury. The brook originates in a small upland wetland in the vicinity of Hapgood Way. A small retention basin is located above Spruce Street at Hapgood Way. Flowing in a generally southeasterly direction, the brook channel roughly parallels Crescent Street as far as Route 9 and the Imperial Village Apartments. From Route 9,the brook flows west under Oak Street and power lines and gradually turns south below Rolfe Avenue. The brook continues in a southerly direction, crossing Oak Street again (between Judick Street and Dalphen Road) and enters an extensive wetland known as "Pead Meadow." Winding its way through the meadow, South Meadow Brook discharges to Flint Pond at South Quinsigamond Avenue between South Brook and Fairview Streets.

Land use in the watershed is about evenly split between open land and low to medium density single family residential. The area on either side of Route 9 contains some industrial and commercial uses as well as a small number of apartment complexes. The upper portion of the watershed is sewered (Howe Ave, Rolfe Ave, Route 9 to Maple Ave.) while the lower portion is served by septic systems.

Figure II-15 outlines the drainage area of the watershed and shows the location of the sampling stations on South Meadow Brook. Three sampling stations were located on the brook under the upper watershed sampling program. Data for these stations is summarized in Tables II-31, II-32 and II-33. Average concentrations of observed parameters at each station over the monitoring period are presented in Table II-34. Table II-35 compares the average concentrations observed at the same station under different sampling programs (F06 314 program; STA 20 Upper Watershed Program).

For discussion and possible management purposes, the brook can be divided into two segments as follows:

Segment 1: Source to Route 9
Segment 2: Route 9 to Flint Pond

SOUTH MEADOW BROOK SAMPLING STATIONS

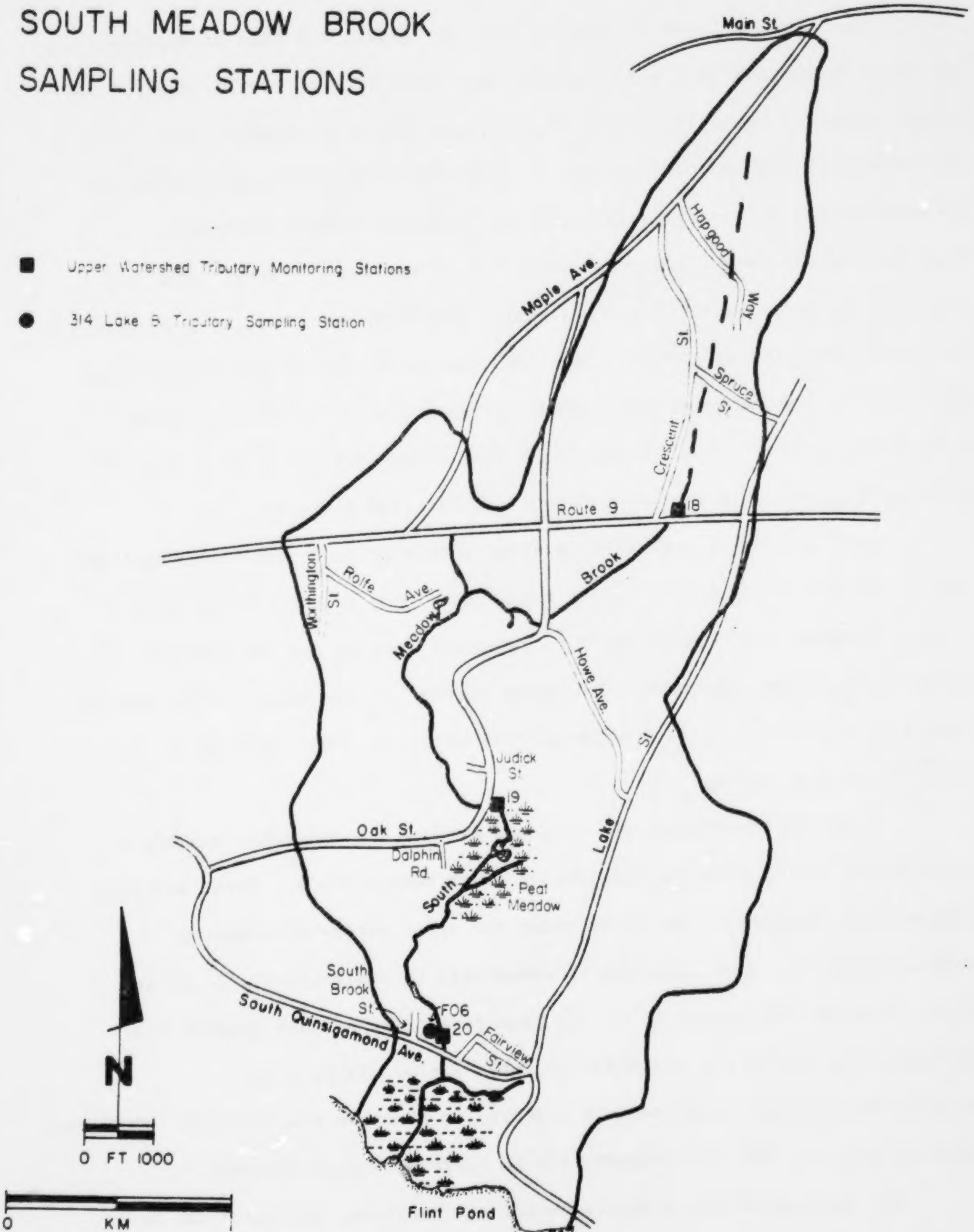
■ Upper Watershed Tributary Monitoring Stations
● 314 Lake & Tributary Sampling Station
Main St.
Maple Ave.
Hapgood Way
Crescent St.
Spruce St.
Route 9
18
Brook
Worthington St.
Rolfe Ave.
Meadow
Howe Ave.
Lake St.
Judick St.
19
Oak St.
Dalphin Rd.
South
Peat Meadow
South Brook St.
South Quinsigamond Ave.
F06
20
Fairview St.
Flint Pond
N
0 FT 1000
0 KM 1

FIGURE II-15

SOUTH MEADOW BROOK -STATION 18
AT ROUTE 9
WATER QUALITY DATA (mg/1)

Parameter (1)	Sept 1980	Oct	Nov	Dec	Jan 1981	Feb	March	April	May	June	Avg.	S.D.
pH (Standard units)	N	N	N	N	N	6.4	6.2	6.3	6.3	N	6.3	0.1
Dissolved Oxygen	O	O	O	O	O	10.7	10.6	9.6	8.9	O	10.0	.64
Temperature °C	T	T	T	T	T	4	6	11	14	T	8.8	4.6
Total Solids						232	240	260	130		216	57
Suspended Solids	S	S	S	S	S	-	-	-	-	S	-	-
Total Hardness	A	A	A	A	A	98	91	80	44	A	78	24
Chloride	M	M	M	M	M	109	86	78	76	M	87	15
Conductivity (2)	P	P	P	P	P	540	245	320	130	P	309	173
Ammonia-Nitrogen	L	L	L	L	L	0.04	0.05	0.03	0.12	L	0.06	0.04
Nitrate-Nitrogen	E	E	E	E	E	3.6	3.9	3.8	1.0	E	3.1	1.4
Nitrite-Nitrogen	D	D	D	D	D	0.002	0.001	0.001	-	D	0.001	0.001
Total Phosphorus						0.16	0.00	0.06	-		0.07	0.08
Total Alkalinity						40	41	24	10		29	15
Total Coliform (3)						20	<10	10	2500		643	1238
Fecal Coliform						<10	<10	<10	1100		283	545
Fecal Strep						<10	<10	-	1670		563	958

1) All units reported as mg/1 except bacteria and conductivity or unless otherwise noted.
2) Conductivity reported as umhos/cm.
3) Bacteria reported as colonies per 100 ml.

TABLE II-32

SOUTH MEADOW BROOK - STATION 19
AT OAK STREET BETWEEN DALPHEN ROAD AND JUDICK STREET
WATER QUALITY DATA (mg/l)

Parameter (1)	Sept 1980	Oct	Nov	Dec	Jan 1981	Feb	March	April	May	June	Avg.	S.D.
pH (Standard units)	6.5	6.7	6.6	6.9	6.8	6.8	6.8	6.8	6.6	6.9	6.7	0.1
Dissolved Oxygen	10.5	11.0	12.8	13.0	13.1	13.0	13.2	11.0	8.5	8.5	11.5	1.9
Temperature °C	11.5	7	1.5	1	1	1	3.5	10	14	13	6.4	5.4
Total Solids	133	160	298	266	166	162	180	210	130	190	190	54
Suspended Solids	-	-	-	-	-	-	-	-	-	-	-	-
Total Hardness	54	66	68	72	78	51	68	78	48	80	66	11.6
Chloride	111	62	94	102	222	51	65	71	74	-	95	52
Conductivity (2)	250	300	380	400	290	340	210	290	150	250	286	76
Ammonia-Nitrogen	0.06	0.03	0.03	0.01	0.04	0.03	0.03	0.05	0.04	0.05	0.04	0.01
Nitrate-Nitrogen	2.7	2.5	2.2	2.3	3.2	3.1	2.8	2.7	0.8	2.5	2.5	0.67
Nitrite-Nitrogen	0.005	-	0.001	0.003	0.008	0.002	0.001	0.001	-	0.010	0.004	0.004
Total Phosphorus	0.08	0.03	0.06	0.06	0.14	0.03	0.00	0.03	-	0.01	0.05	0.04
Total Alkalinity	25	27	24	27	28	46	50	29	12	28	30	11
Total Coliform (3)	1800	1800	800	200	<100	50	70	10	2000	1500	833	849
Fecal Coliform	140	50	90	20	20	10	30	10	920	450	174	294
Fecal Strep	410	110	160	40	<10	<10	<10	10	3000	3600	736	1364

1) All units reported as mg/l except bacteria and conductivity or unless otherwise noted.
2) Conductivity reported as umhos/cm.
3) Bacteria reported as colonies per 100 ml.

TABLE II-33

SOUTH MEADOW BROOK - STATION 20
AT STAFF GAGE ON SOUTH QUINSIGAMOND AVENUE
WATER QUALITY DATA (mg/1)

Parameter (1)	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May	June	Avg.	S.D.
pH (Standard units)	6.4	6.2	6.3	6.6	N	N	6.4	6.5	6.3	6.7	6.4	0.2
Dissolved Oxygen	6.7	7.3	8.7	9.9	O	O	9.5	8.2	4.2	2.9	7.2	2.5
Temperature °C	14.5	6.5	0	0	T	T	4.0	12.0	15.5	17.0	8.7	6.9
Total Solids	106	162	282	162			164	190	110	190	171	55
Suspended Solids	-	-	-	-	S	S	-	-	-	-	-	-
Total Hardness	42	61	61	59	A	A	60	-	40	76	57	12
Chloride	85	51	105	98	M	M	64	70	71	-	78	19
Conductivity (2)	180	250	385	250	P	P	?-	250	-	230	246	36
Ammonia-Nitrogen	0.12	0.08	0.06	0.05	L	L	0.03	0.05	0.04	0.04	0.06	0.03
Nitrate-Nitrogen	1.9	2.0	2.1	2.4	E	E	2.5	2.2	0.4	2.1	2.0	0.7
Nitrite-Nitrogen	0.003	-	0.001	0.002	D	D	<.001	0.001	-	0.004	0.002	0.001
Total Phosphorus	0.16	0.04	0.04	0.11			0.09	0.04	-	0.05	0.08	0.04
Total Alkalinity	28	28	24	24			36	25	14	30	26	6.3
Total Coliform (3)	400	700	1100	400			70	10	2000	480	645	853
Fecal Coliform	70	10	330	<10			10	10	900	50	174	313
Fecal Strep	90	60	200	<10			10	30	3500	500	550	1203

1) All units reported as mg/1 except bacteria and conductivity or unless otherwise noted.
2) Conductivity reported as umhos/cm.
3) Bacteria reported as colonies per 100/ml.

TABLE II-34
AVERAGE DATA VALUES (mg/l)
SOUTH MEADOW BROOK

Parameter	STA 18	STA 19	STA 20
pH (std. units)	6.3	6.7	6.4
Dissolved Oxygen	10.0	11.5	7.2
Temperature °C	8.8	6.4	8.7
Total Solids	216	190	171
Total Hardness	78	66	57
Chloride	87	95	78
Conductivity (umhos/cm)	309	286	246
Ammonia Nitrogen	0.06	0.04	0.06
Nitrate Nitrogen	3.1	2.5	2.0
Nitrite Nitrogen	0.001	0.004	0.002
Total Phosphorus	0.07	0.05	0.08
Total Alkalinity	29	30	26
Total Coliform per 100 ml	643	833	645
Fecal Coliform per 100 ml	283	174	174
Fecal Strep per 100 ml	563	736	550

TABLE II-35

COMPARISON OF NURP AND 314 DATA
(COMMON STATIONS)
SOUTH MEADOW BROOK

Parameter *	F06	STA 20
pH (Standard units)	7.0	6.4
Dissolved Oxygen	7.1	7.2
Temperature °C	13.0	8.7
Total Solids	176	171
Total Hardness	51	57
Chloride	34	78
Conductivity (umhos/cm)	208	246
Ammonia Nitrogen	0.07	0.06
Nitrate Nitrogen	1.1	2.0
Total Phosphorus	0.09	0.08
Total Alkalinity	25	26
Total Coliform per 100 ml	768	645
Fecal Coliform per 100 ml	86	174
Fecal Strep per 100 ml	44	550

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* All concentrations reported in mg/l except where noted.

Water quality data for segment 1 is limited as the brook channel at this point is dry for major portions of the year. As indicated by the sampling dates on Table II-31 for STA 18, only four samples were collected during the period of heaviest runoff,i.e., late winter-early spring. With the exception of the May 1981 sampling data, water quality in this segment is generally good; within the Class B criteria. Nitrate values are high in this segment which may be due to past pollution problems (septic tanks, sewer overflows), excessive fertilizer use or leaf decay. The May sampling date indicates a violation of the Class B bacteria criteria. This violation causes a skewed average bacteria level for STA 18 as reported in Table II-34. This would appear to be due to a failed septic system or other source of sanitary sewage.

Segment 2, as indicated by the water quality data for STA 19 and 20, is generally good and within the Class B criteria with few exceptions. One notable exception is the May sampling period as described in segment 1 which impacted the length of the stream. As indicated in the comparison of data collected at stations F06 and STA 20, the brook is subjected to seasonally high chloride concentrations due to snow and ice control efforts.

TILLY BROOK

The Tilly Brook drainage area,as shown on Figure II-16, lies almost entirely within the Town of Shrewsbury, orginating in the vicinity of the Shrewsbury-Boylston town line. From its origin, the brook is known as West Brook and flows generally southward crossing beneath I-290 just west of Sewall Hill. At that point, the brook enters the Slocum Meadow, an extensive upland wetland which serves the dual purposes of wildlife habitat and flood storage. The brook flows around the St. John's High School Athletic Field and under Main Street and into Mill Pond. From the outlet of Mill Pond the stream is known as Tilly Brook and flows about .5 miles to a 6' X 6' enclosed culvert which channels the brook to its confluence with the

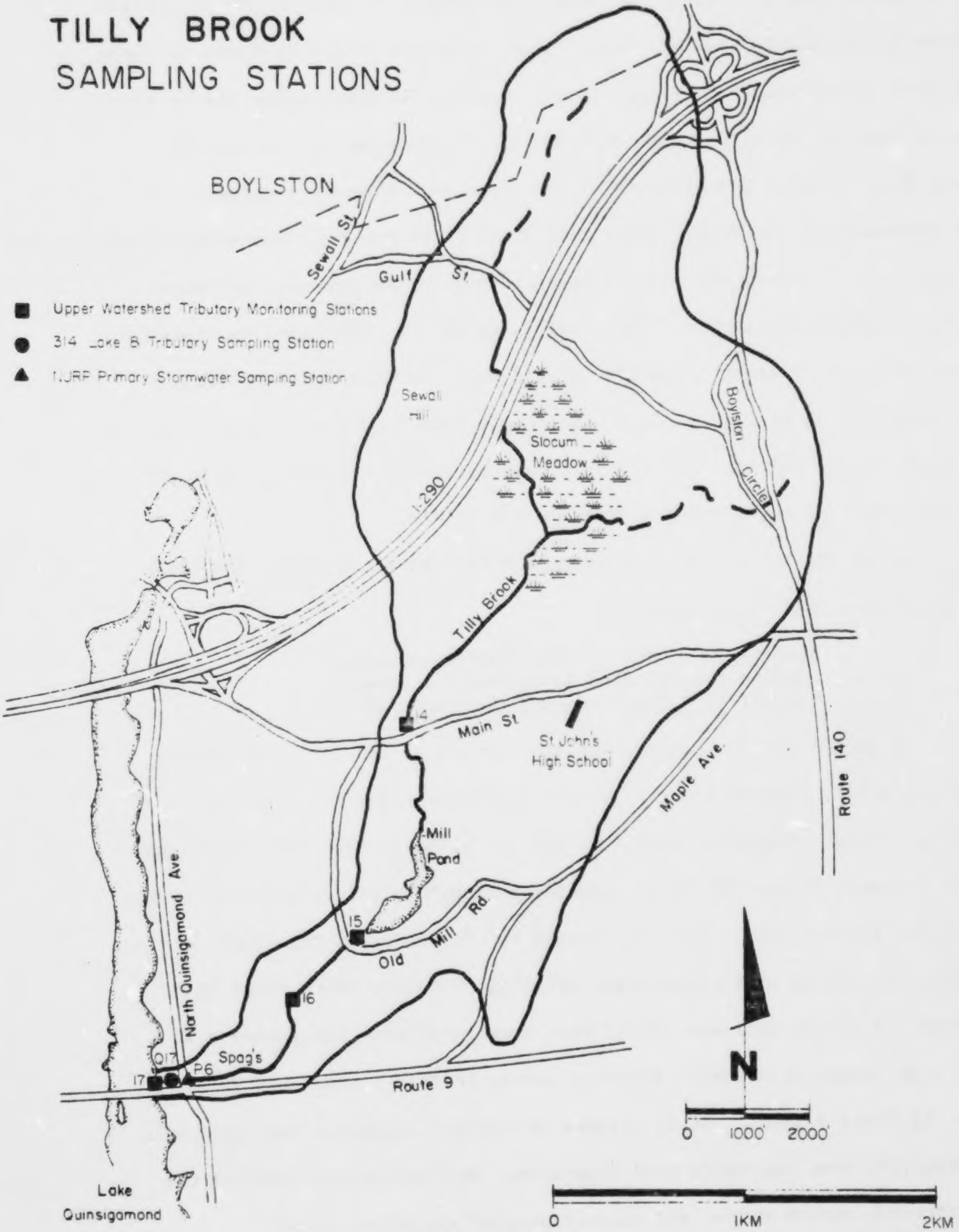

TILLY BROOK
SAMPLING STATIONS
BOYLSTON
■ Upper Watershed Tributary Monitoring Stations
● 314 Lake & Tributary Sampling Station
▲ NURP Primary Stormwater Sampling Station
Sewall St.
Gulf St.
Sewall Hill
I-290
Slocum Meadow
Boylston Circle
Tilly Brook
14
Main St.
St. John's High School
Maple Ave.
Route 140
Mill Pond
15
Old Mill Rd.
16
North Quinsigamond Ave.
Q17
17
P6
Spag's
Route 9
Lake Quinsigamond
N
0
1000'
2000'
0
1KM
2KM

FIGURE II-16

Lake. The watershed drains an area of about 1690 acres.

Above Main Street, the watershed is largely undeveloped with I-290 and the Massachusetts Electric power lines being the most noticeable features. Mill Pond is surrounded by single family residential development and is also host to Camp St. John, a summer camp run by the Xaverian Brothers at St. John's High School. Construction of new homes is presently underway in the area southeast of the Pond. Below Mill Pond, Tilly Brook is predominantly residential until it enters the culvert which runs from the parking lot behind Spag's to Lake Quinsigamond. From that point to the lake land use consists almost entirely of dense commercial development on both sides of Route 9 from Spag's to White City. All of the runoff from this area is channelled to the brook in the culvert. The culvert runs parallel to Route 9 and enters the Lake about 75 yards north of the Route 9 bridge.

Based on its land use and water quality characteristics, the brook may be divided into three segments:

Segment 1: Source to Mill Pond (West Brook)
Segment 2: Mill Pond to Culvert (at Spag's)
Segment 3: Culvert to Lake Quinsigamond

As indicated by the water quality for STA 14 and STA 15 in Tables II-36 and II-37, segment 1 water quality generally meets the Class B criteria. Total phosphorus levels at STA 14, although typically fairly low jumped markedly during the March sampling period,likely indicative of spring fertilizer applications. STA 15, located at the outlet of Mill Pond, reflects the uptake of nutrients and settling of solids which occur in the Pond. A slight increase in chloride levels reflects the increase in paved area around Mill Pond. Bacteria levels in this segment are well below the Class B limit. In an attempt to control excessive weed growth in Mill Pond,the town has begun pond draw-down. Dry-dredging to utilize the nutrient-rich bottom matter and underlying peat are also planned.

No significant changes in water quality conditions occur from segment 1

TABLE II-36

TILLY BROOK - STATION 14
WEST BROOK AT MAIN STREET
WATER QUALITY DATA (mg/1)

Parameter (1)	Sept 1980	Oct	Nov	Dec	Jan 1981	Feb	March	April	May	June	Avg.	S.D.
pH (Standard units)	N	6.2	6.1	6.2	N	6.2	5.9	6.2	6.1	6.7	6.2	0.2
Dissolved Oxygen	O	9.9	11.3	10.2	O	14.3	11.6	10.7	6.9	6.3	10.2	2.2
Temperature °C	T	5.0	-0.5	0	T	1.0	1.0	12.0	15.0	15.5	6.1	7.7
Total Solids		186	192	146		206	124	-	120	210	169	38
Suspended Solids	S	5.5	-	-	S	-	-	-	-	-	-	-
Total Hardness	A	52	51	42	A	82	32	40	32	52	48	16
Chloride	M	54	54	60	M	56	46	60	58	-	55	5
Conductivity (2)	P	180	230	200	P	260	140	180	140	180	189	41
Ammonia-Nitrogen	L	0.01	0.02	0.03	L	0.25	0.03	0.08	0.04	0.33	0.10	0.12
Nitrate-Nitrogen	E	0.2	0.3	0.5	E	2.4	0.5	0.4	0.3	0.1	0.6	0.8
Nitrite-Nitrogen	D	-	0.002	0.002	D	0.001	0.001	0.001	-	0.001	0.001	0.001
Total Phosphorus		0.03	0.00	0.11		0.03	1.44	0.01	-	0.05	0.24	0.53
Total Alkalinity		10	10	12		10	10	9	10	20	11	4
Total Coliform (3)		2200	300	<100		30	<10	<10	260	180	386	741
Fecal Coliform		<10	40	<10		<10	<10	<10	200	50	43	66
Fecal Strep		60	60	10		450	<10	40	850	250	216	298

1) All units reported as mg/1 except bacteria and conductivity or unless otherwise noted.
2) Conductivity reported as umhos/cm.
3) Bacteria reported as colonies per 100 ml.

TABLE II-37

TILLY BROOK - STATION 15
OUTLET AT MILL POND
WATER QUALITY DATA (mg/1)

Parameter (1)	Sept 1980	Oct	Nov	Dec	Jan 1981	Feb	March	April	May	June	Avg.	S.D.
pH (Standard units)	N	6.5	6.6	6.3	6.2	5.9	6.2	6.5	6.5	6.9	6.4	0 .3
Dissolved Oxygen	O	9.4	11.3	11.1	9.2	11.0	12.2	9.2	7.9	6.9	9.8	1.7
Temperature °C	T	10 .0	3.0	3 .0	1 .0	2 .0	4 .0	12.0	18 .0	20.0	8.1	7.2
Total Solids		106	180	152	170	130	148	142	150	140	146	22
Suspended Solids	S	4.0	-	-	-	-	-	-	-	-	-	-
Total Hardness	A	34	41	48	68	32	40	42	40	40	43	11
Chloride	M	43	46	57	133	50	57	61	64	-	64	29
Conductivity (2)	P	140	180	180	260	220	155	170	150	160	179	38
Ammonia-Nitrogen	L	0.02	0.02	0.02	0 .08	0.20	0.03	0 .01	0.05	0 .08	0.06	0 .06
Nitrate-Nitrogen	E	0.2	0.2	0.4	0 .5	0.7	0.5	0 .3	0.4	0 .3	0.4	0 .2
Nitrite-Nitrogen	D	-	0.001	0.003	0 .001	0.006	0.001	0 .001	-	0 .001	0.002	0 .002
Total Phosphorus		0.02	0.09	0.09	0 .12	0.16	0.04	0 .04	-	0 .001	0.07	0 .05
Total Alkalinity		14	12	13	19	10	14	11	13	15	13	3
Total Coliform (3)		700	100	200	<100	40	<10	20	200	370	193	222
Fecal Coliform		150	20	<10	<10	<10	<10	<10	120	20	40	55
Fecal Strep		70	<10	<10	<10	450	60	10	160	100	98	142

1) All units reported as mg/1 except bacteria and conductivity or unless otherwise noted.
2) Conductivity reported as umhos/cm.
3) Bacteria reported as colonies per 100 ml.

TABLE II-38

TILLY BROOK - STATION 16

AT CULVERT ABOVE SPAG'S PARKING LOT
WATER QUALITY DATA (mg/1)

Parameter (1)	Sept 1980	Oct	Nov	Dec	Jan 1981	Feb	March	April	May	June	Avg.	S.D.
pH (Standard Units)	N	6.6	6.9	6.7	N	6.2	6.3	6.7	6.6	7.0	6.6	0.3
Dissolved Oxygen	O	10.6	12.6	13.2	O	12.7	12.7	9.8	8.0	7.3	10.9	2.3
Temperature ^{o}C	T	7	3	2	T	1.5	5	12	17.5	19.5	8.4	7.1
Total Solids		120	170	134		130	122	140	110	130	132	18
Suspended Solids	S	4.5	-	-	S	-	-	-	-	-	-	-
Total Hardness	A	33	40	31	A	31	40	41	36	44	37	5
Chloride	M	46	38	-	M	44	60	65	64	-	53	12
Conductivity (2)	P	120	180	190	P	210	155	180	140	160	167	29
Ammonia-Nitrogen	L	0.01	0.02	0.02	L	0.19	0.04	0.06	0.05	0.08	0.06	0.06
Nitrate-Nitrogen	E	0.3	0.2	0.4	E	0.7	0.5	0.3	0.3	0.4	0.4	0.2
Nitrite-Nitrogen	D	-	0.001	0.003	P	0.004	0.001	0.001	-	0.001	0.002	0.001
Total Phosphorus		0.02	0.02	0.04		0.16	0.09	0.03	-	0.01	0.05	0.05
Total Alkalinity		14	16	12		10	12	11	14	18	13	3
Total Coliform (3)		600	100	<100		80	<10	50	230	560	216	242
Fecal Coliform		<10	<10	<10		10	<10	<10	160	300	62.5	109
Fecal Strep		90	<10	<10		450	<10	20	170	2100	376	720

1) All units reported as mg/1 except bacteria and conductivity or unless otherwise noted.
2) Conductivity reported as umhos/cm.
3) Bacteria reported as colonies per 100 ml.

TABLE II-39

TILLY BROOK - STATION 17
AT STAFF GAGE ON HARVEY PLACE DRAIN
WATER QUALITY DATA (mg/l)

Parameter (1)	Sept 1980	Oct	Nov	Dec	Jan 1981	Feb	March	April	May	June
pH (Standard units)	-	N	N	6.9	N	N	N	N	N	N
Dissolved Oxygen	7.1	O	O	13.1	O	O	O	O	O	O
Temperature °C	17.0	T	T	2.0	T	T	T	T	T	T
Total Solids	139			176						
Suspended Solids	13.1	S	S	-	S	S	S	S	S	S
Total Hardness	59	A	A	45	A	A	A	A	A	A
Chloride	87	M	M	72	M	M	M	M	M	M
Conductivity (2)	180	P	P	225	P	P	P	P	P	P
Ammonia -Nitrogen	0.08	L	L	0.02	L	L	L	L	L	L
Nitrate -Nitrogen	1.0	E	E	0.5	E	E	E	E	E	E
Nitrite -Nitrogen	0.002	D	D	0.003	D	D	D	D	D	D
Total Phosphorus	0.12			0.06						
Total Alkalinity	28			14						
Total Coliform (3)	5200			<100						
Fecal Coliform	210			<10						
Fecal Strep	270			10						

1) All units reported as mg/l except bacteria and conductivity or unless otherwise noted.
2) Conductivity reported as umhos/cm.
3) Bacteria reported as colonies per 100 ml.

TABLE II-40

AVERAGE DATA VALUES (mg/1)
TILLY BROOK

Parameter	STA 14	STA 15	STA 16	Q 17
pH (Standard units)	6.2	6.4	6.6	7.1
Dissolved Oxygen	10.2	9.8	10.9	9.0
Temperature °C	6.1	8.1	8.4	16.2
Total Solids	169	146	132	114
Total Hardness	48	43	37	38
Chloride	55	64	53	34
Conductivity(umhos/cm)	189	179	167	173
Ammonia Nitrogen	.10	0.06	0.06	0.06
Nitrate Nitrogen	0.6	0.4	0.4	0.3
Nitrite Nitrogen	0.001	0.002	0.002	-
Total Phosphorus	0.24	0.07	0.05	0.05
Total Alkalinity	11	13	13	19
Total Coliform per 100 ml	386	193	216	30,879
Fecal Coliform per 100 ml	43	40	62	2804
Fecal Strep per 100 ml	216	98	376	202

to segment 2 as indicated by the data reported for STA 16 in Table II-38. Although much of the land area within this segment is zoned for single family residential development, most of the available land remains open. The brook channel from the outlet of Mill Pond to the culvert at Spag's parking lot has been rock-lined along the bottom and sides. Several brook crossings have been constructed in anticipation of future growth.

Segment 3 consists of the remaining portion of the brook which is channeled to the lake via a 6' X 6' box culvert. Several surface drains from parking lots, streets and other paved areas run into the brook over this section. At its confluence with the lake, the elevation of the bottom of the culvert is below the surface elevation of the lake, which allows lake water to backflow well up into the culvert. During low-flow periods, this presented problems in terms of sampling and differentiating between brook and lake water due to mixing. This was not a problem during high-flow and/or storm flow periods. For this reason, sampling of STA 17 during the Upper Watershed Sampling Program was curtailed. Sampling was conducted at this locationas station Q17 under the 314 sampling program and as primary stormwater sampling station P6 which will be further described in the section on stormwater sampling.

As shown in Table II-40, there is little or no difference in water chemistry between STA 16 and Q17 other than those parameters which would be affected by seasonal differences(e.g. temperature, D.O.,chlorides, solids). A significant increase is observed in bacteria levels which violate the Class B criteria. These levels were observed to fluctuate over the 314 sampling period but consistently violated the criteria. During stormwater sampling events, bacteria levels increased by several orders of magnitude suggesting a source or sources of either dilute or filtered sewage.

NEWTON POND

The Newton Pond drainage area, shown in Figure II-17, originates in the Town of Boylston as a series of small brooks which collectively form Sewall Brook in the vicinity of Route 140. The Brook flows into Sewall Pond and from there

NEWTON POND
SAMPLING STATION

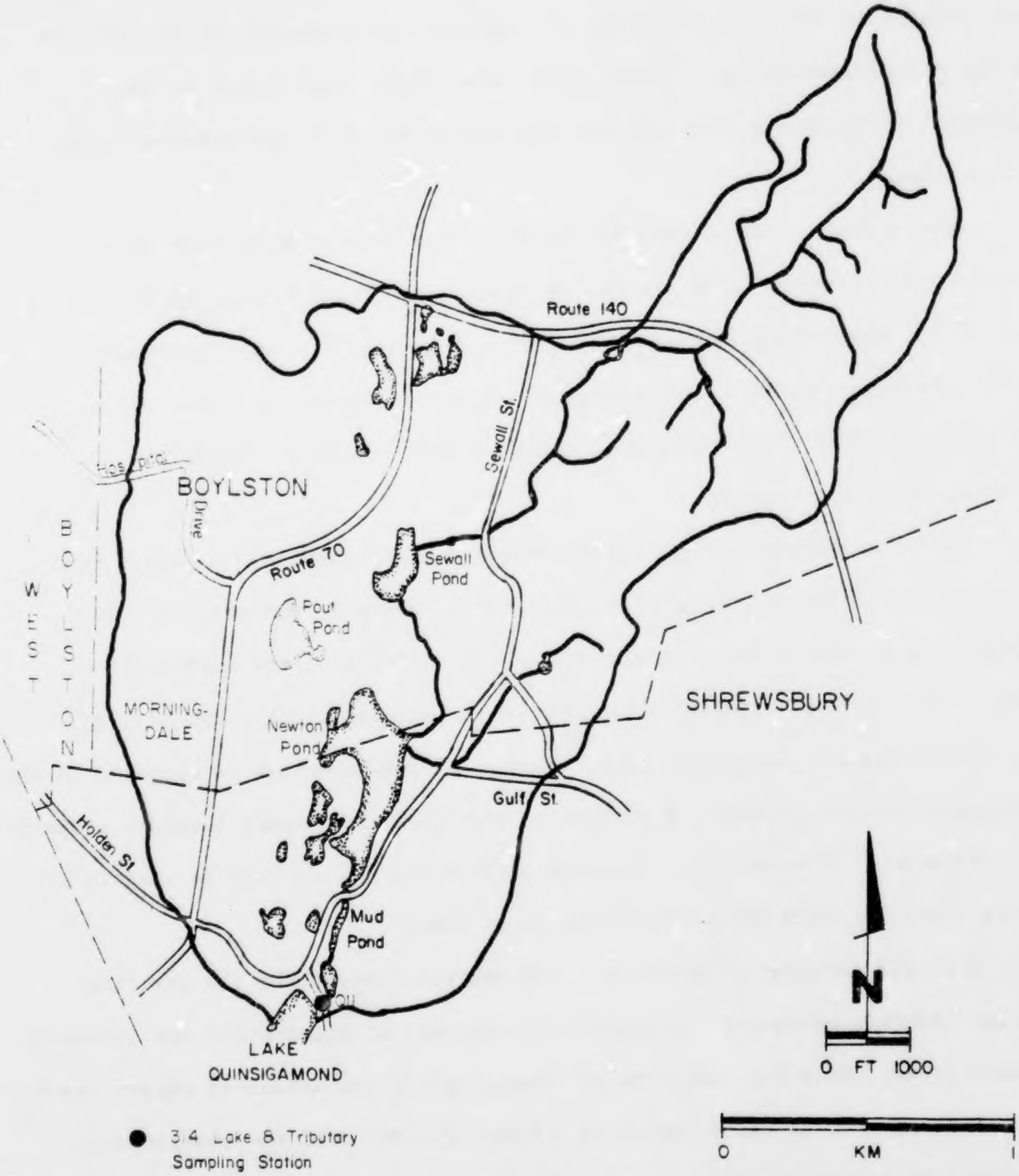

Route 140
Sewall St.
Hospital
BOYLSTON
Drive
Route 70
Sewall Pond
Pout Pond
WEST BOYLSTON
MORNING-DALE
Newton Pond
SHREWSBURY
Gulf St.
Holden St
Mud Pond
LAKE QUINSIGAMOND
N
0 FT 1000
0 KM 1
● 3,4 Lake & Tributary Sampling Station

FIGURE II-17

into Newton Pond, just over the Shrewsbury town line. Several small ponds located on either side of Route 70, South of Route 140, drain to Newton Pond via Sewall Pond. Pout Pond is also within this area. Although there is no surface connection between Pout Pond and Newton Pond, the Ponds are connected via the underlying groundwater aquifer in this drainage area. Similarly, several small ponds located in the Worcester Sand & Gravel pit are connected to Newton Pond via the groundwater regime. These ponds have likely been formed by the excavation of the gravel pit and are representative of the groundwater level in that area.

Newton Pond itself straddles the town line between Shrewsbury and Boylston. The overflow from the dam at Newton Pond flows into a small pond known as Mud Pond, into another small pond and finally into the northern end of Lake Quinsigamond via a corrugated steel culvert under Holden Street. This point is often referred to as the Newton Pond outlet or "overflow" in various sampling reports.

The northeastern portion of the drainage area tributary to Sewall Pond is largely undeveloped due to high water table, bedrock, and small hills. The central and western portions along Route 70 in Boylston are moderately to heavily developed with single family dwellings, new apartment complexes, and light commercial and industrial development. This development is centered in the Morningdale section of town. A portion of the Worcester County Hospital property also drains to this watershed. The area surrounding Newton Pond is largely in private ownership with sparse shoreline development.

A single sampling station, Q11, was monitored under the 314 sampling program. Average parameter concentrations observed at station Q11 are presented in Table II-41. With the exception of occassionally low dissolved oxygen levels, this tributary systems meets the Class B water quality criteria consistently. Variations in dissolved oxygen may be attributed to deposition and decomposition of organic matter in Mud Pond and temperature effects. These

TABLE II-41
NEWTON POND OUTLET
314 SAMPLING PROGRAM STATION Q11
AVERAGE CONCENTRATIONS

Parameter *	Units	Average Concentration
Dissolved Oxygen	MG/L	8.1
Temperature	°C	14.5
Conductivity	UHOS/CM	124
Alkalinity	MG/L	18
Hardness	MG/L	30
pH	STD.UNITS	7.2
Chloride	MG/L	22
Sulfate	MG/L	8.4
Iron	MG/L	0.18
Manganese	MG/L	0.04
Total Nitrogen	MG/L	0.65
Total Kjeldahl N	MG/L	0.55
Organic N	MG/L	0.51
Ammonia-N	MG/L	0.04
Nitrate-N	MG/L	0.10
Inorganic N	MG/L	0.14
Total P	MG/L	0.04
Total Dissolved P	MG/L	0.03
Silica	MG/L	0.6
Apparent Color	PT-CO UNITS	17
Total Solids	MG/L	104
Suspended Solids	MG/L	2.9
Total Coliforms	COUNTS/100 ML	428
Fecal Coliforms	COUNTS/100 ML	30
Fecal Strep	COUNTS/100 ML	14

* Concentrations expressed as mg/l unless otherwise noted.

occasional oxygen depletions do not appear to adversely effect the overall quality characterictics of the area. Owing to its land use characteristics and consistently good water quality,segmentation of the watershed was not neccssary.

BILLINGS BROOK

As shown in Figure II-18, the drainage area of Billings Brook lies entirely within the Town of Shrewsbury. A relatively small basin, the brook originates as an intermittent stream in the Slocum Meadow marsh situated between Route I-290 and Main Street. From its source, the brook flows southerly, roughly parallel to the West Brook system. Below Main Street, the brook has been re-routed and channelized through an extensive gravel pit system. The former Shrewsbury landfill, located in part of the gravel pit, was closed and sealed in 1974. The area is still used as a major gravel mining area. A sedimentation basin was constructed on the brook to control erosion and downstream filtration. A small but active wetland located upstream of Quinsigamond Avenue further acts as a sediment trap prior to the brook's discharge to the lake at Eagle Head Cove.

Land use in the drainage area of Billings Brook is variable. At its outlet to the lake, the watershed is dominated by the gravel pit system, described above. Included in the drainage area are unimproved road surfaces and trailways, a few industrial and commercial establishments, and further to the north, near its source, Slocum Meadow and Sewall Hill, a relatively undeveloped area. Land use in the southern portion of the drainage area, south of the gravel pit and along Old Mill Road.consists primarily of moderate density single family homes.

A single sampling station, station Q13, located at the mouth of the brook below Quinsigamond Avenue, was sampled under the 314 sampling program. Data averages are presented in Table II-42. With the exception of occassional dissolved oxygen violations, Billings Brook generally meets Class B water quality criteria.

BILLINGS BROOK
SAMPLING STATION

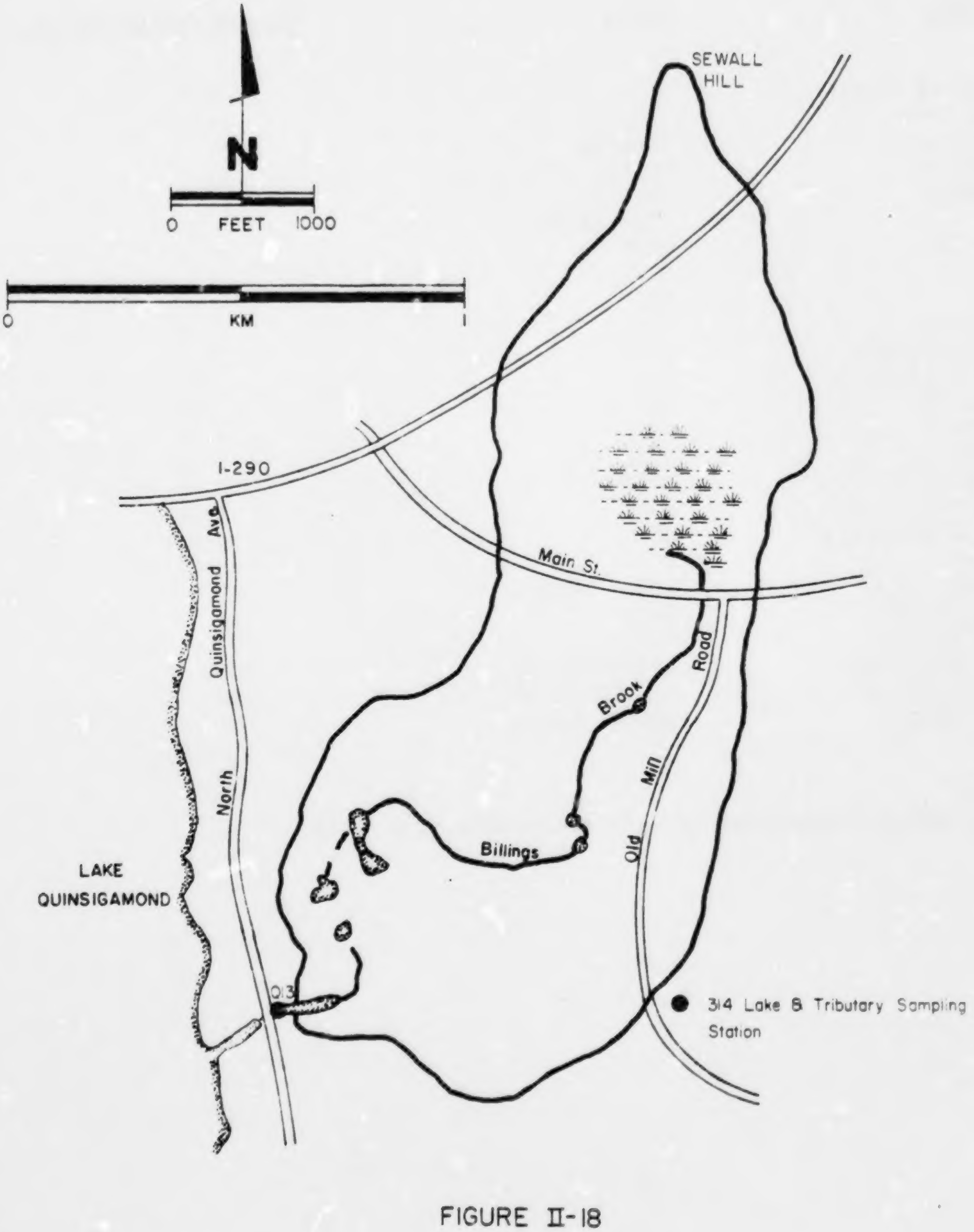

N
0 FEET 1000
0 KM 1
SEWALL HILL
I-290
Main St.
Quinsigamond Ave.
North
Old Mill Road
Billings Brook
LAKE QUINSIGAMOND
Q3
● 314 Lake & Tributary Sampling Station

FIGURE II-18

TABLE II -42
BILLINGS BROOK
314 SAMPLING PROGRAM STATION Q13
AVERAGE CONCENTRATIONS

Parameter *	Units	Average Concentration
Dissolved Oxygen	MG/L	7.7
Temperature	°C	13.7
Conductivity	UHOS/CM	224
Alkalinity	MG/L	20
Hardness	MG/L	54
pH	STD.UNITS	6.9
Chloride	MG/L	43
Sulfate	MG/L	17.1
Iron	MG/L	0.67
Manganese	MG/L	0.09
Total Nitrogen	MG/L	1.32
Total Kjeldahl N	MG/L	0.71
Organic N	MG/L	0.61
Ammonia-N	MG/L	0.10
Nitrate-N	MG/L	0.61
Inorganic N	MG/L	0.71
Total P	MG/L	0.06
Total Dissolved P	MG/L	0.03
Silica	MG/L	6.2
Apparent Color	PT-CO UNITS	17.5
Total Solids	MG/L	146
Susp. Solids	MG/L	3.9
Total Coliforms	COUNTS/100 ML	302
Fecal Coliforms	COUNTS/100 ML	48
Fecal Strep	COUNTS/100 ML	41

* Concentrations expressed as mg/l unless otherwise noted.

Due primarily to land use characteristics and for the development of management strategies to prevent pollution in this drainage area, two segments have been defined as follows:

Segment 1: Source to Main St.(Shrewsbury)
Segment 2: Main Street to Lake Quinsigamond

JORDAN POND

Jordan Pond is a rather small pond whose drainage area lies entirely within the town of Shrewsbury. The maximum width of the pond is approximately 1200 feet. It is located within the Fairlawn area characterized by moderate to heavy urbanization to the north and moderate urbanization further to the south. The area southeast of the pond consists mainly of woods and brush. Dwellings abutting the pond itself are sparse and road surfaces near the pond are unimproved. The body of the pond is situated just over one-half mile east of Lake Quinsigamond and is connected to the Lake via the Jordan Pond outlet.

A powerline passes over the northeast corner of the pond. The pond is used for both contact and non-contact recreation, primarily swimming and fishing. The pond and its drainage area are shown in Figure II-19.

A single sampling station at the outlet of the pond, station Q18, was monitored under the 314 sampling program. The outlet was flowing on only four of the sixteen sampling dates. A summary of the data averages is presented in Table II-43. With the exception of the bacteria levels, water quality generally meets the Class B criteria. Based on individual sampling date data, the bacteria criteria were violated on two of the four sampling dates. The developed area north and west of the pond are sewered,while the area east of the pond is reliant on septic systems for wastewater disposal. The bacteria problem may be related to either or both systems. Although the sewer system is of recent construction and materials, there is a possibility of either un-connected or misconnected house connections. No problems such as bypasses or overflows from the Ridgeland Road wastewater

62

JORDAN POND
SAMPLING STATIONS

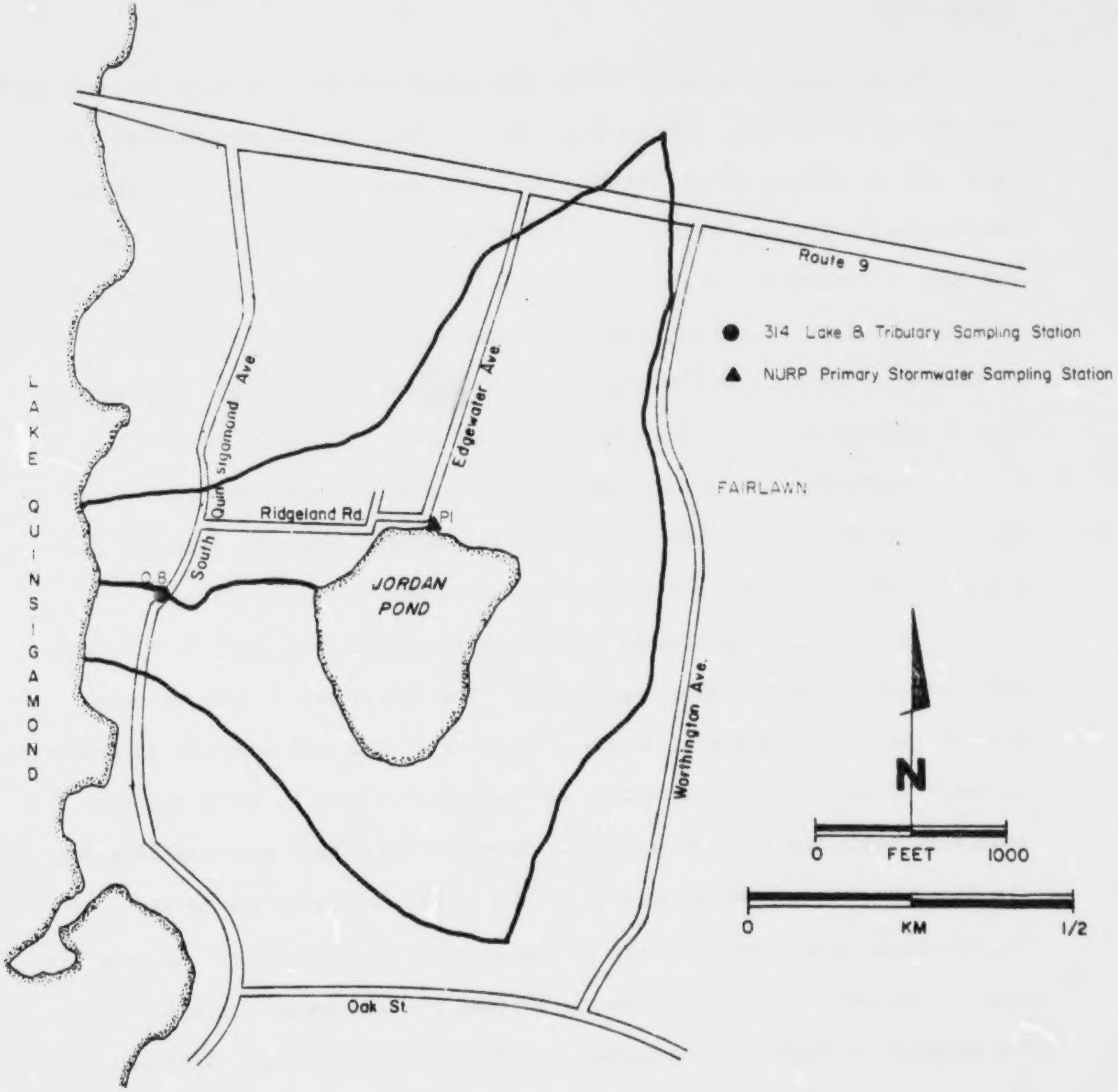

Route 9
● 314 Lake & Tributary Sampling Station
▲ NURP Primary Stormwater Sampling Station
South Quinsigamond Ave.
Edgewater Ave.
Ridgeland Rd.
P1
Q8
JORDAN POND
FAIRLAWN
Worthington Ave.
LAKE QUINSIGAMOND
Oak St.
N
0 FEET 1000
0 KM 1/2

FIGURE II-19

TABLE II-43
JORDAN POND
314 SAMPLING PROGRAM STATION Q18
AVERAGE CONCENTRATIONS

Parameter *	Units	Average Concentration
Dissolved Oxygen	MG/L	8.3
Temperature	°C	15.3
Conductivity	UHOS/CM	155
Alkalinity	MG/L	23
Hardness	MG/L	30
pH	STD.UNITS	7.2
Chloride	MG/L	27
Sulfate	MG/L	11.8
Iron	MG/L	0.13
Manganese	MG/L	0.02
Total Nitrogen	MG/L	0.67
Total Kjeldahl N	MG/L	0.57
Organic N	MG/L	0.50
Ammonia-N	MG/L	0.07
Nitrate-N	MG/L	0.10
Inorganic N	MG/L	0.17
Total P	MG/L	0.04
Total Dissolved P	MG/L	0.01
Silica	MG/L	0.10
Apparent Color	PT-CO UNITS	10.0
Total Solids	MG/L	143
Suspended Solids	MG/L	0.8
Total Coliforms	COUNTS/100 ML	592
Fecal Coliforms	COUNTS/100 ML	982
Fecal Strep	COUNTS/100 ML	185

* Concentrations expressed as mg/l unless otherwise noted.

pumping station have been reported.

A stormwater sampling station, P1, was located at the discharge of the Edgewater Avenue storm sewer. Bacteria levels during storm events were observed to range from the thousands to the tens of thousands (fecal coliform), well in excess of the Class B criteria. This area is completely sewered, suggesting either cross-connections or leaks from the sanitary to the storm sewer. This sampling station will be further discussed in the section on stormwater sampling. (See Chapter III,Section C.4)

A sampling location at Edgewater Avenue monitored over several years by the Shrewsbury Health Department also indicates repeated coliform standard violations. Sampling of the swimming beach at the Jordan Pond Recreation Area, at the south end of the pond, by the town Health Department indicates that the water at the beach generally meets the Class B criteria.

BONNIE BROOK

Bonnie Brook drains a small portion of East Millbury and the Wyman-Gordan complex in North Grafton. It contributes approximately 18% of the total tributary flow into Lake Quinsigamond and Flint Pond. The brook discharges to a small cove at the south end of Flint Pond via a culvert under Creeper Hill Road, as shown in Figure II-20.

There are no known direct wastewater or treatment facility dishcarges to Bonnie Brook. There are, however, indirect discharges from the Wyman-Gordon complex. An on-site treatment facility at the Millbury Plant discharges via the storm drainage system and both the Grafton and Millbury plants discharge cooling and stormwater. There are also three stormwater discharges from the Maplewood area which discharge to Bonnie Brook.

In terms of water quality in Flint Pond, this brook is a major source

BONNIE BROOK
SAMPLING STATION

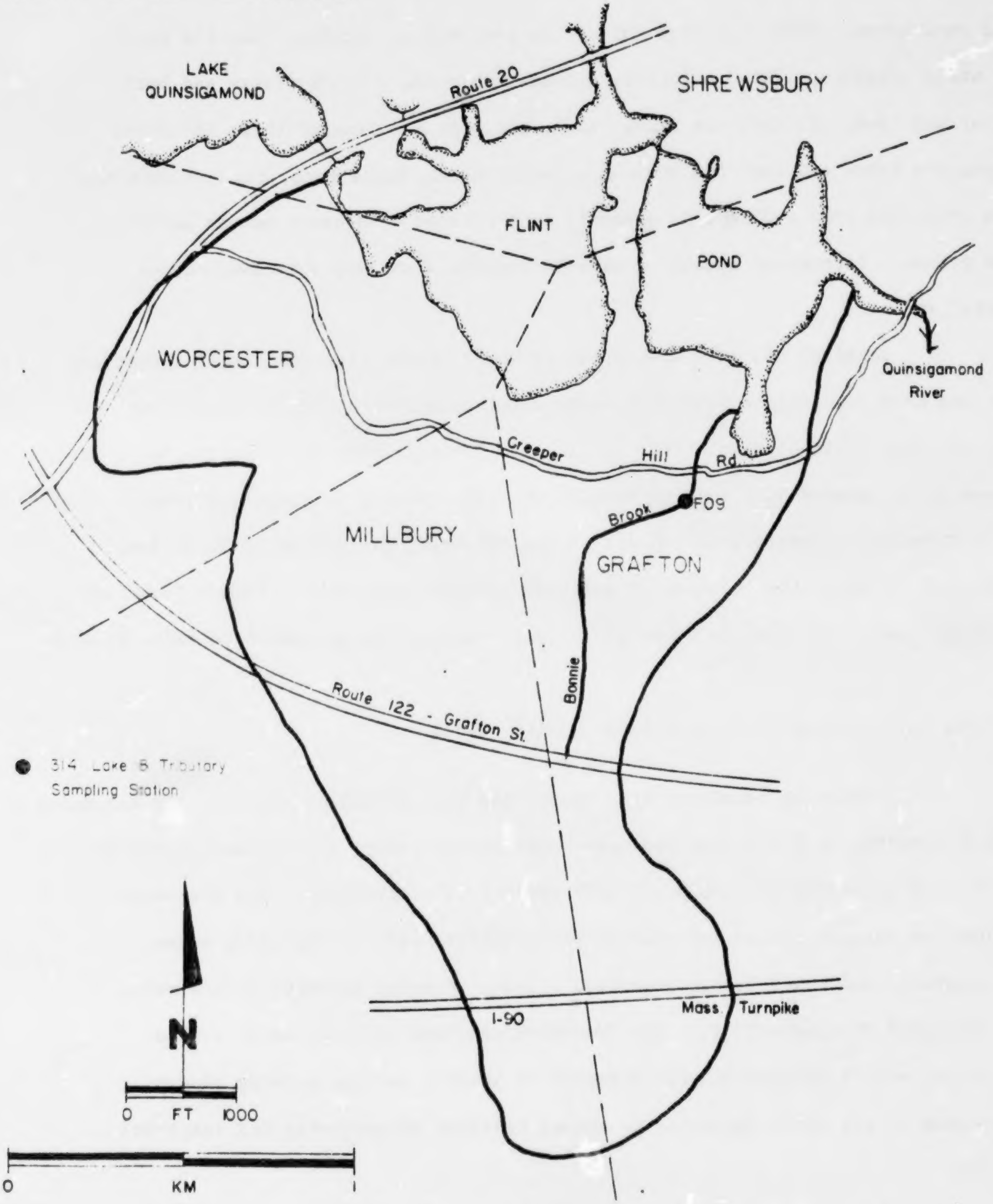

LAKE QUINSIGAMOND
Route 20
SHREWSBURY
FLINT
POND
WORCESTER
Quinsigamond River
Creeper Hill Rd
F09
Brook
MILLBURY
GRAFTON
Bonnie
Route 122 - Grafton St.
● 314 Lake & Tributary Sampling Station
I-90
Mass. Turnpike
N
0 FT 1000
0 KM 1

FIGURE II-20

of pollutants. When Bonnie Brook was sampled during the DWPC 1971 intensive survey, data showed high levels of suspended solids, oil and grease, nitrate and phosphorus. Data collected during the 1980 survey indicate that the brook is still grossly polluted. Solids, nitrate, chloride , conductivity and both total and fecal coliform are high. Also, sediment sampling of three locations along the brook and from the cove into which Bonnie Brook runs, all indicate that the brook and pond sediment is severely contaminated with heavy metals and oil and grease. Particular metals of concern include aluminum, chromium, copper, nickel and zinc.

Based on the data available, it would appear that industrial operations are the most significant source of heavy metal pollution to Bonnie Brook and the southern basin of Flint Pond. It is also possible that other metals fabricating firms along Creeper Hill Road in Grafton are contributing to these problems, both directly to Bonnie Brook and/or in the receiving water area of Flint Pond. Figure II-21 shows the location of sediment sampling stations on Bonnie Brook and in Flint Pond. Sediment data for those four stations are presented in Table II-44.

D. Lake Quinsigamond/Flint Pond Water Quality Model

A modeling framework for predicting the effects of nutrient and suspended solids loadings on Flint Pond and Lake Quinsigamond water quality was developed by William W. Walker Jr., Ph.D., a NURP project sub-consultant. The framework focuses on eutrophication and related water quality aspects including algae, transparency and hypolimnetic dissolved oxygen. Control pathways in the model are depicted in Figure II-22. The framework consists of a series of linked empirical and theoretical models designed to predict average growing season responses of the above variables to annual loadings of nutrients and suspended solids.

Two versions of the model framework were developed and calibrated: a spatially-segmented version and a completely-mixed version. The completely-

BONNIE BROOK
SEDIMENT SAMPLING STATIONS

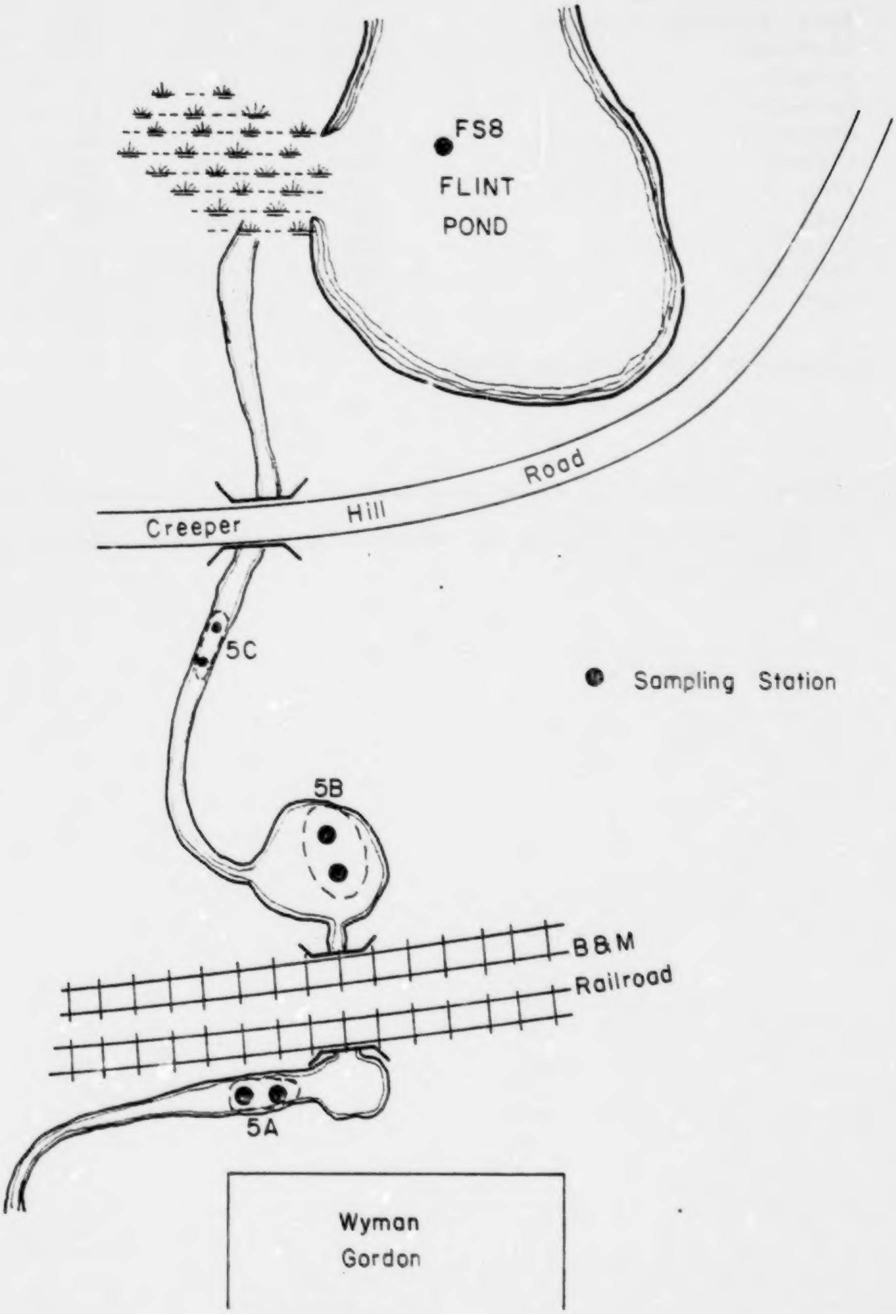

FS8
FLINT
POND
Creeper Hill Road
5C
● Sampling Station
5B
B&M
Railroad
5A
Wyman
Gordon

FIGURE II-21

TABLE II-44

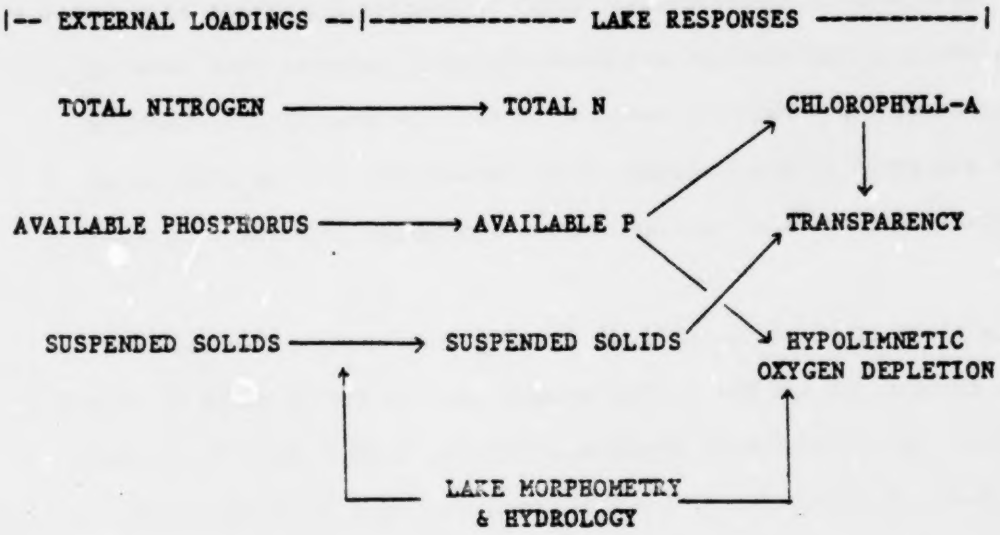
BONNIE BROOK - FLINT POND
SEDIMENT DATA

Parameter*	Stations 5A	 5B	 5C	 FS8
Total Phosphorus	900	1050	500	2000
Total Kjeldahl Nitrogen	3650	4325	2625	9300
Aluminum	39500	34900	3710	110386
Arsenic	23	24	23	92
Cadmium	1.6	3.5	1.7	8.0
Chromium	527	638	88	582
Copper	1813	1718	337	3010
Iron	31310	35100	17030	42147
Lead	264	302	98	7.2
Nickel	330	354	126	843
Potasium	1055	1080	556	903
Zinc	396	3540	809	7627
Sediment Pollution Index (SPI)	12.9	21.1	7.1	38.9

---

* All concentrations in dry weights (mg/kg) except Sediment Pollution Index (unitless)

Figure II-22
Control Pathways in the Water Quality Model


EXTERNAL LOADINGS
LAKE RESPONSES
TOTAL NITROGEN
TOTAL N
CHLOROPHYLL-A
AVAILABLE PHOSPHORUS
AVAILABLE P
TRANSPARENCY
SUSPENDED SOLIDS
SUSPENDED SOLIDS
HYPOLIMNETIC OXYGEN DEPLETION
LAKE MORPHOMETRY & HYDROLOGY

mixed version predicts spatially-averaged surface water conditions, although the hypolimnetic basins of Lake Quinsigamond are treated individually. Although this approach is somewhat simplistic, it is considered justified by the data analyses which indicate that while Flint Pond tends to have lower transparency than Lake Quinsigamond owing to higher concentrations of suspended solids and color; spatial variations in chlorophyll-a, total phosphorus and dissolved phosphorus are not statistically significant and are generally small compared with temporal variations. The segmented version is used to describe the spatial distributions of nutrient and suspended solids loadings. This version may also be utilized to evaluate the potential effects of various control strategies proposed in specific watersheds.

Table II-45 lists estimated total loadings and outflows derived from watershed model simulations and the outflow gauging station for 12 years of record. The total loadings include estimated atmospheric inputs, surface runoff, and base flows for each year. The averages of these loading components over all years are given at the bottom of the table. The average outflow from the lake, 30.6 hm3/yr, is somewhat below the period-of-record mean discharge, 32.7 hm3/yr, estimated as 89% of the mean flow measured at the USGS gauge between 1939 and 1979, based upon relative drainage area. The simulated loadings included some especially dry years (1964-66), as well as Hurricane Agnes (1972). On the average, base flow is the most significant source of total nitrogen, while surface runoff is the most important source of total phosphorus, dissolved phosphorus, and suspended solids. Calculated loadings for 1980 were generally above-average, while outflow was somewhat below average.

Table II-46 lists lake responses to the annual loadings given in Table II-45. These simulations are not necessarily replications of historical water quality conditions, particularly in the earlier years, because they assume that land uses and other factors influencing loading, such as sewer overflows and point sources, were similar to 1980 conditions. The purpose of these simulations

Table II-45

Simulated Loadings

Year	Total Outflow	Susp. Solids	Total N	Total P	Dis. P	Available P		
						Fa=0.0	0.1	0.2
1964	23.2	343	30.0	2.47	.87	.87	1.03	1.19
1965	12.6	635	19.4	3.57	.82	.82	1.09	1.37
1966	14.7	769	21.7	4.23	.93	.93	1.26	1.59
1967	32.2	978	42.4	5.70	1.50	1.50	1.92	2.34
1968	33.4	821	42.4	5.04	1.39	1.39	1.76	2.12
1969	31.4	680	75.5	4.30	1.25	1.25	1.55	1.86
1970	32.7	861	44.0	5.22	1.47	1.47	1.85	2.22
1971	25.3	666	31.9	4.00	1.10	1.10	1.39	1.68
1972	53.8	1258	66.5	7.75	2.20	2.20	2.76	3.31
1973	38.8	736	43.8	4.75	1.45	1.45	1.78	2.11
1979	41.9	1151	54.8	6.99	1.89	1.89	2.40	2.91
1980	26.6	991	38.8	5.68	1.43	1.43	1.85	2.28
mean	30.6	824	39.4	4.96	1.36	1.36	1.72	2.08
atmos.	1.3	0	2.9	.09	.09	.09	.09	.09
base	17.1	43	20.5	.75	.46	.46	.49	.52
runoff	12.2	781	16.0	4.12	.81	.81	1.14	1.47

* all loadings in metric tons per year;
flow in millon cubic meters per year

Table II-46
Results of Water Quality Simulations *

Year	Susp. Solids (g/m3)	Avail. P (mg/m3)	Total N (mg/m3)	N/P -	Chl-a (mg/m3)	Secchi Depth (m)	Days of O2 Supply (days)	Trout Space **
1964	0.7	11	489	46	2.3	3.5	215	.29
1965	1.3	13	381	30	2.9	2.9	182	.13
1966	1.6	14	410	29	3.4	2.6	162	.04
1967	1.9	18	603	33	4.7	2.2	130	.00
1968	1.6	16	592	36	4.1	2.5	143	.00
1969	1.4	15	539	36	3.6	2.7	157	.02
1970	1.7	17	620	36	4.5	2.3	135	.00
1971	1.3	14	486	35	3.3	2.8	165	.05
1972	2.4	22	723	34	6.1	1.9	110	.00
1973	1.4	16	569	36	3.9	2.6	147	.00
1979	2.2	21	684	33	5.7	2.0	114	.00
1980	2.0	19	600	33	4.9	2.2	127	.00
mean	1.6	16	558	35	4.1	2.5	149	.05
std dev	0.5	3	103	4	1.1	0.4	30	.09
min	0.7	11	381	29	2.3	1.9	110	.00
max	2.4	22	723	46	6.1	3.5	215	.29

* based upon simulated loadings in TableII-45;Fa=0.1

** fraction of hypolimnion with oxygen concentration > 5 mg/liter on September 1.

is to assess the influences of year-to-year variabilities in weather patterns and hydrology on lake conditions for a given watershed condition. Estimated year-to-year variabilities are high, with available phosphorus varying by as much as a factor of 2 (11-22 mg/m3). Actual year-to-year variabilities would tend to be somewhat lower than those calculated because conditions would not necessarily equilibrate to each set of annual loadings. Generally, simulated water quality was better during drier years and concentrations in 1979 and 1980 were relatively high.

Table II-47 compares predicted and observed water quality conditions for 1979, based upon data summarized previously (Meta Systems, 1980). Simulated loadings and concentrations were somewhat greater in 1979 compared with 1980. The observed data reflect this to some extent, although it is difficult to compare the 1979 and the 1980 summary statistics because the monitoring program was considerably less intensive in 1979 and did not include the entire stratified period. Predicted concentrations of suspended solids and total nitrogen are somewhat lower than median observed values, but within the respective interquartile ranges.

The spatial distributions of 1980 loadings in various lake areas are listed in Table II-48. The lake has been divided into a series of 6 segments and loading components,(atmospheric, runoff, base flow) have been computed separately for each. Segment A (above Main Street) is the most heavily loaded, since it is directly impacted by the two largest watersheds (Poor Farm Brook and Newton Pond). Areal sediment and nutrient loadings are roughly an order of magnitude greater in this segment compared with the others. This area of the lake is relatively shallow, has a dense aquatic weed population, and, based upon the computed loadings, is subject to considerable sedimentation. Based upon the estimated suspended solids settling velocity of 150 m/yr and water loading of 85 m/yr, about two thirds of the influent suspended solids are trapped within this segment, or about 1.5 kg/m2-yr.

Depending upon sediment phosphorus chemistry and the role of aquatic

Table II-47
Comparison of Model Predictions with 1979 Data

Response Variable	Observed Values 25%	 50%	 75%	Predicted
Chlorophyll-a (mg/m3)	4.2	4.8	6.1	5.7
Secchi Depth (m)	1.9	2.1	2.4	2.0
Days of Oxygen Supply*		123		114
Non-Algal Sus. Solids (g/m3)	1.8	3.3	4.8	2.2
Total Nitrogen (mg/m3)	550	870	1190	684
Available Phosphorus (mg/m3)				21

* volume-weighted average of 3 hypolimnetic basins; using morphometric data

Table -II-48
Spatial Distribution of Loadings - 1980

		LAKE SEGMENT *					
		A	B	C	D	E	F
Surface Area	(km2)	.11	.65	.63	.67	.34	.69
Volume	(hm3)	.11	7.60	6.55	3.79	.88	1.91
Watershed Area	(km2)	21.4	14.9	6.6	5.0	8.1	2.3
total loadings							
Water	(hm3/yr)	9.3	6.7	3.1	2.5	3.7	1.3
Susp. Solids	(mt/yr)	260	226	190	138	88	83
Total N	(mt/yr)	10.6	9.2	5.7	4.3	6.5	2.5
Total P	(mt/yr)	1.65	1.33	0.99	0.73	0.54	0.48
Dissolved P	(mt/yr)	0.40	0.35	0.25	0.18	0.16	0.09
Avail. P	(mt/yr)	0.52	0.44	0.33	0.23	0.20	0.13
areal loadings							
Water	(m/yr)	85	10	4.8	3.7	10.8	1.9
Sus. Solids	(g/m2-yr)	2360	347	292	205	259	120
Total N	(g/m2-yr)	96	14	8.8	6.4	19	3.6
Total P	(g/m2-yr)	15.0	2.0	1.5	1.1	1.6	0.7
Dissolved P	(g/m2-yr)	3.6	.54	.38	.27	.47	.13
Avail. P	(g/m2-yr)	4.7	.68	.51	.34	.59	.19

* segment locations:

A = north of Lincoln Street
B = north of Route 9 bridge
C = north of Stoneland Brook
D = north of outlets to Flint Pond
E = Flint Pond (north)
F = Flint Pond (south)

weeds in regenerating bottom sediment phosphorus, a considerable portion of the particulate phosphorus entering the northernmost segment from Poor Farm Brook and Newton Pond may never reach the main body of the lake. While no water quality monitoring stations were located within this segment, nutrient and suspended solids concentrations are probably higher than those measured in other lake segments and are not comparable to the model predictions. Small ponds on lake tributaries (Newton, City Farm, West Brook, Jordan) may also act as sediment traps but would not be expected to remove appreciable quantities of dissolved nutrients because of the relatively small surface areas and short hydraulic residence times.

Areal loadings are more uniform among Segments B-F. This uniformity, coupled with the effects of horizontal mixing among the segments, explains the relative uniformity of average nutrient and chlorophyll measurements from one end of the lake to the other. The relatively short hydraulic detention time of Flint Pond permits little change in water quality as it flows from Lake Quinsigamond to the outlet. A model which calculates water quality responses separately for each segment has also been developed, but is not described here because horizontal variations in nutrients and chlorophyll are minimal and the simpler, completely-mixed model described above appears to be adequate to describe the average load/response characteristics of the lakes.

Nutrient and suspended solids balances calculated separately for Lake Quinsigamond and Flint Pond in 1980 summarized in Table II-49. Discharges from Lake Quinsigamond to Flint Pond are estimated from the water balance and using concentrations measured at Station F07. The Flint Pond balances indicate that direct loadings (mostly surface runoff) are most important in the case of suspended solids, while inputs from upstream Lake Quinsigamond are most important for nutrients. In evaluating management strategies for Flint Pond, however, the potential nutrient inputs from shoreline septic systems should be added to the nutrient balances. The shoreline of Flint Pond is highly developed with year-round residences, about 110 in number, based upon the most recent U.S.G.S. topographic

Table II-49
1980 Nutrient and Suspended Solids Balances Calculated Separately for Lake Quinsigamond and Flint Pond

Component	Water hm3/yr	Susp. Sol. mt/yr	Total N mt/yr	Total P mt/yr	Dis. P mt/yr
Lake Quinsigamond					
Surface Runoff	9.4	792	15.7	4.16	.79
Base Flow	11.3	20	11.9	.47	.33
Atmospheric	0.9	-	2.1	.06	.06
Total Load	21.6	812	29.7	4.70	1.18
Discharge	21.6	61	23.1	1.21	.48
Percent Retained	0%	93%	22%	74%	59%
Flint Pond					
Inflow from Quins.	21.6	61	23.1	1.21	.48
Surface Runoff	2.8	164	3.3	.86	.16
Base Flow	1.7	7	4.6	.13	.06
Atmospheric Load	0.5	-	1.0	.03	.03
Total Load	26.6	232	32.0	2.23	.73
Discharge	26.6	53	25.0	1.25	.53
Percent Retained	0%	77%	22%	44%	27%

map. Assuming an average of 3 inhabitants per house and an annual total phosphorus contribution of 2 kg/capita, a maximum potential loading of 660 kg/year exists, compared to the estimated dissolved phosphorus loading of 730 kg/yr from other sources. Any phosphorus reaching the lake from septic tanks is expected to be in dissolved, or available form. The estimate of 660 kg/year corresponds to the worse case, i.e., phosphorus-saturated soils. If 20% of the systems are saturated and/or malfunctioning hydraulically, the loading of 132 kg/yr would still represent 18% of the loadings from other sources. Thus, septic systems are potential factors in the current condition of Flint Pond. Lake surveys indicate higher fecal coliform and fecal streptococci counts at Station F05, compared with other Flint Pond stations. This station is closest to the west shoreline of the pond, the area with greatest shoreline residential development. Higher counts may indicate that at least some of the septic systems are not functioning properly. A current survey of shoreline residences, septic system characteristics, and soil characteristics would be needed to develop an improved assessment of phosphorus loading from unsewered residences.

E. Summary of Conclusions

Based on the proceeding water quality data and lake modeling analysis, the following conclusions can be drawn with regard to present water quality conditions in Lake Quinsigamond and Flint Pond:

1. Water quality in Lake Quinsigamond and Flint Pond during 1980 was generally similar to that measured in 1971 and 1979.

2. Chlorophyll, transparency, and hypolimnetic oxygen depletion rates indicate that Quinsigamond is in a late mesotrophic stage. Despite its similar water quality, the relatively shallow Flint Pond should probably be classified as eutrophic owing to its aquatic weed densities.

3. The three hypolimnetic basins of Lake Quinsigamond have spring oxygen supplies ranging from 72 to 140 days, compared with a 200-day stratified

period. Based upon oxygen and temperature profiles, the potential cold-water fish habitat is limited to the thermocline (20-30 feet) in late summer.

4. A typical seasonal succession of dominant algal types from diatoms in spring, to greens in early and mid-summer, to blue-greens in late summer, and back to diatoms in the fall was observed in both lakes, as regulated by temperature, light, and nutrient supplies.

5. Periods of algal growth limitation by phosphorus, silica, and nitrogen are indicated and reflected in the algal type shifts. Of these nutrients, phosphorus is considered to be the most important from a control point of view, because it is limiting for most of the period of oxygen deficit development and because of the potential for nitrogen fixation by blue-green algae. Since water transparency averaged over 2 meters, light is not likely to be unusually important as a regulating factor.

6. Analysis of lake data in relation to antecendent rainfall periods indicate significantly higher concentrations of total phosphorus, dissolved phosphorus, and coliform bacteria on wet days, as compared with dry days. This reflects urban runoff loading impacts. In late summer, the system tends to shift from nitrogen to phosphorus limitation during extended dry periods (about one week).

7. The level of primary production in the lakes (as gauged by chlorophyll-a, transparency, and hypolimnetic oxygen deficit) is best correlated with dry-weather and/or spring total phosphorus measurements.

8. Lake data indicate that an average of 49% of the light attenuation in Quinsigamond surface waters can be attributed to algae and algae-related materials (detritus, zooplankton), 21% to suspended solids, 25% to color and 5% background (water). Corresponding percentages for Flint Pond are 34%, 29%, 33% and 4%.

9. Fecal coliform counts in the lakes averaged more than an order of magnitude below the standard for body-contact recreation. Fecal coliform counts exceeded

73

200/100 ml in 2 samples out of 104 in Lake Quinsigamond and in 0 samples out of 96 in Flint Pond. In the main lake, counts tended to be higher on sample days which followed within two days of significant rainstorms and at stations which were closest to the most concentrated source (Belmont Street Storm Drain). A more intensive lake monitoring program would be needed to properly assess the extent and significance of short-term violations in the coliform standard in certain areas of the lake immediately following storm events.

10. Total coliform counts averaged 62/100 ml in Quinsigamond and 46/100 ml in Flint Pond, compared with a state Class A (drinking water) standard of 50/100 ml. As in the case of fecal coliforms, spatial and temporal variabilities are large and certain areas of each lake may be more suitable than others as a reserve water supply from a microbiological standpoint.

11. Nutrient balance calculations indicate that surface runoff accounted for 87% of the total phosphorus, 67% of the dissolved phosphorus, 96% of the suspended solids and 49% of the total nitrogen discharged to these lakes during 1980. The remaining loadings are attributed to tributary base flows and atmospheric inputs.

12. Morphometric characteristics and hypolimnetic iron, manganese, and phosphorus measurements suggest that the potential for internal recycling of dissolved phosphorus from the anaerobic hypolimnion to the mixed layer is limited. Release of bottom sediment phosphorus from shallow, littoral areas via diffusion, wind-induced re-suspension, and uptake by rooted aquatic plants may be significant in certain areas of the lake.

13. Lake mass balances and literature studies suggest that between 0 and 20% of the particulate phosphorus loadings entering the lake are eventually available to support algal growth through the mechanisms discussed above (12). Assumptions concerning the bio-availability of particulate phosphorus are critical to the assessment of potential control strategies and direct measurements should be undertaken as part of control strategy design.

14. Dissolved phosphorus inputs to Flint Pond from unsewered residences

is nominally estimated at 18% of other sources. A refined analysis of the watershed, soils, and on-site disposal systems could improve the accuracy of this estimate.

III. Problem Assessment - Identification of Pollution Sources

A. Introduction

Based on the water quality and other data and the lake modeling analysis presented in the preceding chapter, the major pollution problems identified in the Lake Quinsigamond-Flint Pond drainage basin include hypolimnetic dissolved oxygen depletion, eutrophication, weed growth and sedimentation which are all symptoms of eutrophication. The primary pollutants associated with these problems are nutrients (primarily dissolved phosphorus and nitrogen) and suspended solids. Other pollution parameters that are of concern include bacteria and selected heavy metals.

In order to develop control strategies that will be effective in controlling these identified pollutants and thus correct the problems they have created, it is essential to identify the sources of pollution and the relative contributions of each of the various pollutants associated with each source. The purpose of this chapter is to identify the sources of pollution to Lake Quinsigamond and Flint Pond and the degree of pollution associated with them.

Pollution sources typically fall into one of two categories, point or nonpoint sources. Point sources include wastewater treatment plant discharges (including sewerage systems and pumping stations, etc.), industrial discharges and combined sewer overflows. Nonpoint sources include subsurface waste disposal systems; landfills; erosion and sedimentation (e.g. land disturbing activities including construction, sand and gravel mining, forestry operations, etc.) and stormwater runoff.

In the following sections, pollution problems identified in each of the communities draining to Lake Quinsigamond and Flint Pond are discussed under the pollution source categories listed above.

B. Point Sources

1. Municipal Sewerage Systems

Boylston

At present, the town relies on septic systems for wastewater disposal. Refer to the Septic System heading under Nonpoint Sources.

Grafton

A small portion of the Maplewood section of town lies within the Flint Pond - Bonnie Brook Drainage area. Although a sewer line was constructed along Route 122 to serve Wyman Gordan, the Maplewood area and Creeper Hill Road are presently unsewered. Wastewater is transported to the town's treatment facility which discharges to the Blackstone River. No problems have been identified or are known to be associated with the Grafton sewerage system. Refer to the Septic System heading under Nonpoint Sources for any discussion of septic system related problems along Creeper Hill Road and the Maplewood area.

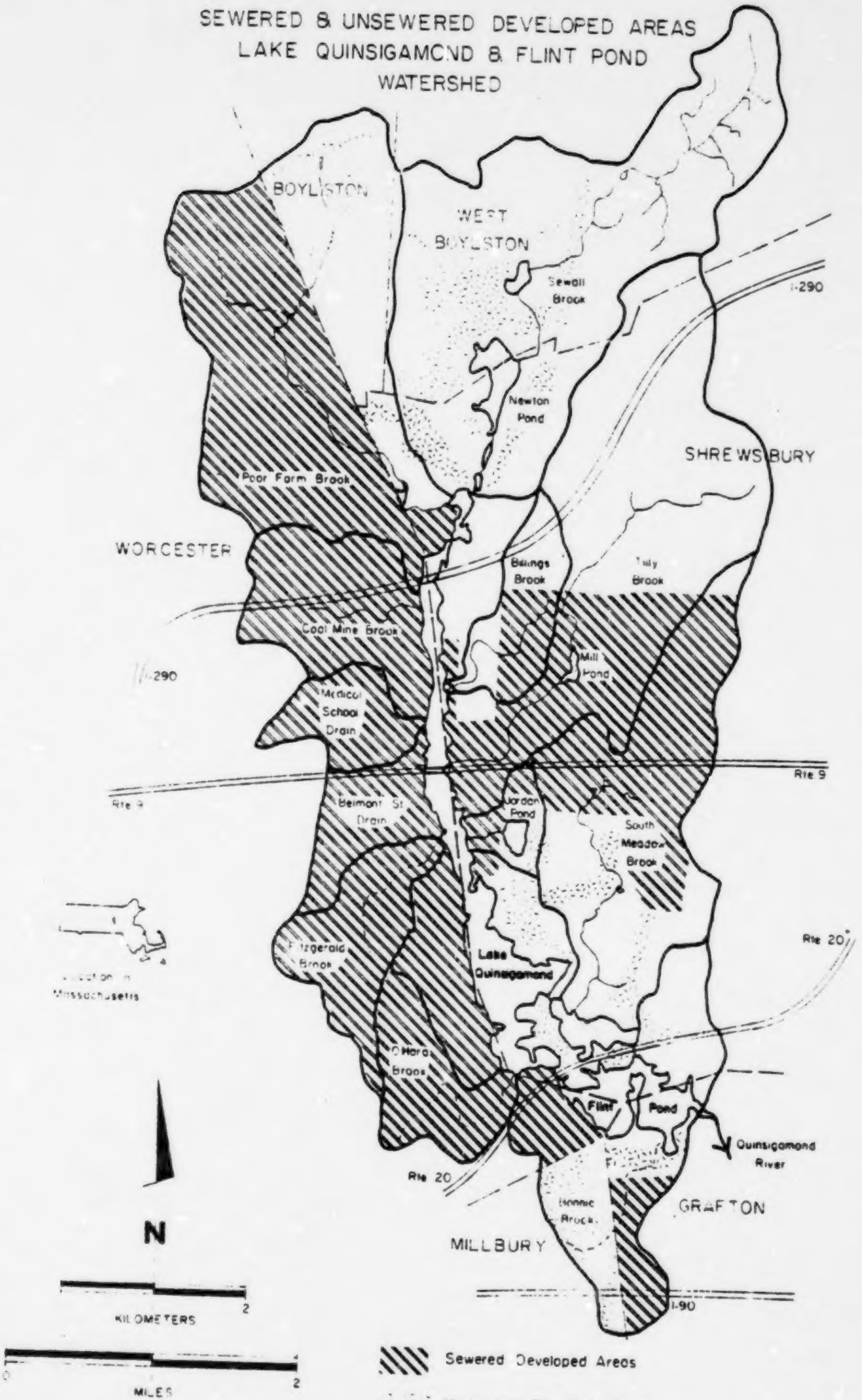
Millbury

A small portion of the East Millbury section of town(Wheelocke Avenue-Route 122) lies within the Flint Pond-Bonnie Brook Drainage area. The area is presently unsewered. Refer to the section on Septic Systems under Nonpoint Sources for any discussion of problems in this area.

Shrewsbury

A major portion of the more densely developed sections of town are served by a sewerage system (refer to Figure III-1). The area served by the sewerage system (within the Lake Quinsigamond watershed) generally includes the town center, Main Street, Maple Street,Quinsigamond Ave.(North to Eagle Head Cove, South to Oak Street), Route 140, Howe Avenue, Route 9, Lakewood Drive and adjoining areas. Remaining developed areas within the lake's drainage area are served by septic systems.

Wastewater collected within this sewerage system is pumped out of the Lake Quinsigamond drainage basin to the town's treatment plant which discharges to the Assabet River in Northboro. Seven sewage pumping stations are located in the



SEWERED & UNSEWERED DEVELOPED AREAS
LAKE QUINSIGAMOND & FLINT POND
WATERSHED

BOYLSTON
WEST BOYLSTON
Sewall Brook
I-290
Newton Pond
SHREWSBURY
Poor Farm Brook
WORCESTER
Billings Brook
Tilly Brook
Coal Mine Brook
Mill Pond
I-290
Medical School Drain
Rte 9
Rte 9
Belmont St Drain
Jordan Pond
South Meadow Brook
Location in Massachusetts
Fitzgerald Brook
Lake Quinsigamond
Rte 20
O'Hara Brook
Flint Pond
Quinsigamond River
Rte 20
Bonnie Brook
GRAFTON
MILLBURY
I-90
N
KILOMETERS
2
0
MILES
2
▨ Sewered Developed Areas
Unsewered Developed Areas

FIGURE III-1

Quinsigamond drainage area, including the following:

1. Old Mill Road (at Old Mill Pond) - siphon
2. Harvey Place (above Tilly Brook at edge of Lake)
3. Jordan Pond (at Ridgeland Road)
4. Rolfe Avenue
5. Howe Avenue
6. Eaglehead Cove (siphon)
7. Topsfield Circle

By agreement with the City of Worcester and the Upper Blackstone Water Pollution Abatement District, the Goddard Industrial Park is sewered and connected to the Worcester sewerage system.

As discussed in the tributary water quality analysis in the preceeding chapter, bacteria levels in Tilly Brook , Jordan Pond and South Meadow Brook may be related to sewer system problems. Sewer systems problems could conceivably include clogging, excess inflow/infiltration, leaky joints and seals, pipe failure, power failure and vandalism, among others. In the past, power failures (particularly at pumping stations), clogging in the sewer lines and vandalism to the sewer lines, particularly at manholes, have led to direct bypasses and overflows to receiving streams. Only one incident of a sewer overflow was encountered during this project. Deliberate clogging(vandalism) of the sewer line at a manhole resulted in a discharge to South Meadow Brook. The town sewer department corrected the problem shortly after the overflow was reported. With the provision of back-up power supply and emergency pumping equipment, overflows from pumping stations due to power failures, high flow or clogging have virtually been eliminated as major pollution sources. During the course of the project, town officials identified and corrected a significant source of flow to Tilly Brook. A large capacity septic system serving a building on the grounds of the Worcester Foundation for Experimental Biology was found to be unconnected to the sewer system. Additional monitoring is required to determine the impacts of having removed this pollution source from Tilly Brook. The Harvey Place pumping station should be inspected frequently for any sign of leaky seals or other problem owing to its location relative to recreational use of the lake and Tilly Brook and for the protection of residents of the area. The Jordan Pond pumping station should similarly be inspected and a sewer and storm drain inspection program should be conducted in the Jordan Pond area to identify and subsequently correct any misconnections, leaks, and/or broken pipes and joints.

West Boylston

West Boylston does not have a sewerage system, relying instead on individual on-site septic systems. Refer to the section on Septic Systems in the Nonpoint source discussion.

Worcester

The City of Worcester operates a sewerage system of over 650 miles. The entire area within the Lake's watershed is included in the sewer system. All wastewater collected in the system is pumped to the UBWPAD treatment facility where it is treated and discharged to the Blackstone River. In order to deliver the wastewater to the treatment facility, pumping is required. Five pumping stations are located in the Lake drainage area as follows:

1. Bird Street
2. Lake Avenue(south)
3. Whitla Avenue
4. Bridle Path
5. Suntaug Road

A number of problems associated with the sewerage system, including the pumping stations, have caused water quality problems in the Lake, and several tributaries. Although many of these problems have been corrected in the past five to ten years, problems still exist as identified by the Lake and tributary water quality data discussed in the previous chapter.

Problems associated with the sewerage system itself can be attributed to any one, or combination of, a number of causes. There may include the age of the system, inadequate capacity, sewer design (twin invert manholes, etc.), inflow/infiltration, changes in the chemical composition of urban wastewater (alkali/acid household cleaners ,detergents,disinfectants, etc.) and vandalism (deliberate destruction and/or clogging of manholes and sewer lines with rags, stones, dirt, trees and other debris).

Specific actions taken by the city, through the Department of Public Works, the Health Department or both, to correct problems with the sewerage system within the Lake Quinsigamond drainage area include the following:

1. Provision of auxillary power at all pumping stations ;
2. Construction of baffles in twin invert manholes;
3. Concrete capping of manholes in vandalism-prone areas; and
4. Construction of the North Lake Avenue Interceptor

Additionally, actions planned by the city include the following:

1. Construction of the Northwest and Maplewood Interceptors. (These projects, scheduled for construction in 1982, will eliminate the major point source problems affecting Poor Farm Brook);
2. Elimination of the Bird Street pumping station,
3. Construction of a new South Lake Avenue Interceptor ; and
4. Continue construction of baffles in twin invert manholes

Based on the sampling data, O'Hara, Fitzgerald, Coal Mine and Poor Farm Brooks and the Belmont Street Drain are receiving intermittant discharges of wastewater. These can usually be related to one or more of the problem causes already described. The city has an on-going program to identify and correct problems such as these as they are identified, either by the Public Works sewer maintenance crews or by the Health Department water quality inspection team. The use of a city-owned sewer inspection television system has greatly improved the DPW's ability to identify and correct problems. Following the completion of the major construction activities identified above, the city's sewer inspection and maintenance program, complemented by the Health Department sampling programs will likely yield significant reductions of bacteria, solids and organic loads to these tributaries and to the Lake.

Following the initial tributary sampling program, Health Department and NURP project staff initiated a pilot program to identify and, where possible, correct sources of sanitary sewage to the storm sewer system, This effort has focused on the Coal Mine Brook and Fitzgerald Brook watersheds. Several misconnections, clogged sewers, broken lines and one still unidentified source were discovered during the course of this project

All identified misconnections were issued reconnection orders from the Health Department. Broken lines, clogged sewers and other maintenance related problems have been reported to the city Public Works Department. Further investigation is planned by the Health Department. Sampling will be conducted on these areas in 1982 to assess the effectiveness and continuing need for this type of investigation and repair program. Priority areas for additional work include the Belmont Street Drain area and O'Hara Brook.

2. Industrial Discharges

At this time, there are only two industries in the Lake Quinsigamond/ Flint Pond watershed with point discharges. Sprague Electric Company, located on East Mountain Street in Worcester discharges cooling water to Poor Farm Brook via a on-site detention pond. No water quality problems are known to be related to this discharge.

The Wyman-Gordan Company operates two plants located on Route 122 in Millbury and Grafton. Each plant has multiple discharges to Bonnie Brook. The Millbury plant has two permitted discharges. Both are storm sewers with outfalls to the brook. One storm sewer also handles the discharge from the Millbury plant's on-site wastewater treatment facility. The other storm sewer also receives a cooling water discharge. The Grafton plant originally had five storm sewer outfalls to Bonnie Brook . Several of these also handled both contact and non-contact cooling water discharges. As of December 1, 1981, two of the storm sewers carrying non-contact cooling water and a portion of a third carrying contact cooling water were removed by a interceptor which carries the flow to an on-site treatment facility which includes oil-water separation and detention basins. As reflected in both the water quality and sediment data for Bonnie Brook and the southern basin of Flint Pond, the discharges from both plants have had a significant impact on both the brook and the pond. (See Chapter II Section c.2- Bonnie Brooks Pages)

The two industries discussed above are the only point source industrial discharges to the Lake or its tributaries. Other industrial-related problems will be discussed in subsequent nonpoint source sections.

C. Nonpoint Sources

1. Sub-surface Disposal Systems

Boylston

The town of Boylston is totally reliant on septic systems for wastewater disposal. No major pollution problems have been identified with respect to septic systems as having an impact on Lake Quinsigamond. However, Sewall Pond has begun to show signs of excessive nutrient levels input to the pond following increased development in this area. As this problem is likely related to septic systems, the town should consider establishing requirements for septic system maintenance and inspection including mandatory pumping schedules. The encouragement of water conservation measures would also help to improve septic system operating characteristics and extend the useful life of the system. The town should initiate a long-range evaluation of wastewater disposal options for the town including continued reliance on septic system; alternative on-site disposal systems and/or centralized sewerage as possible alternatives.

Grafton

The Maplewood area of town (generally the area along Route 122 west of Route 140) and the area along Creeper Hill Road presently rely on septic systems for wastewater disposal. The Maplewood area is scheduled for complete sewering under Phase II of the town's sewer plan (within two years). There are no plans to provide sewerage along Creeper Hill Road.

Although no major water quality problems in Bonnie Brook and Flint Pond can be related to septic systems, it is probable that any impacts are masked by the presence of industrial sources of pollution to this area. Sewering the Maplewood area should effectively prevent any future problems from occurring. The town should institute a maintenance and inspection program including mandatory pumping of septic systems for the Creeper Hill Road area (and other non-sewered areas of the town). Industrial subsurface disposal systems should be inspected biannually. Water conservation should be encouraged.

Millbury

No water quality problems related to septic systems were identified from the unsewered East Millbury area. The area is slated to be sewered under the town's long-range sewerage plan.

Shrewsbury

There are three major developed areas within the Lake drainage area served by septic systems for wastewater disposal. These include the following:

1. Flint Pond - Southern Lake Quinsigamond: Oak Street, South Quinsigamond Avenue,(Oak St.to Lake St.), Lake Street, Route 20 and the Edgemere section ;
2. East of Jordan Pond; and
3. Newton Pond - Sewall Street - Gulf Street and Holden Street - Clinton Street areas.

Septic system-related water quality problems have been identified in South Meadow Brook and Flint Pond (Area 1) and as a possible source of bacterial contaminated problems in Jordan Pond (Area 2). No water quality problems with respect to septic systems have been identified in the Newton Pond area (Area 3). Both the delineation of the three areas and the assessment of problems associated with them are in close agreement with the updated step 1 facilities plan for the town prepared by Fay, Spofford & Throndike (engineering consultants)(dated April, 1981). The facilities plan calls for providing sewerage to Areas 1 and 2 and continued reliance on septic systems in Area 3.

Based on the water quality modeling, which indicated that septic systems contribute as much as 18% of the total annual phosphorus load to Flint Pond, Area 1 should be given a high priority for the provision of sewerage. It is recommended that a septic system maintenance program including a mandatory pumping frequency should be implemented by the town for these areas until the sewer system construction occurs. This program should be implemented and remain in effect in the area (or areas of town) which are expected to continue to rely on septic systems for wastewater disposal.

West Boylston

The entire town relies on septic systems for wastewater disposal. As indicated by the water quality monitoring data for Poor Farm Brook, bacteria and other measured parameters suggest a source or sources of sewage above Shrewsbury Street in West Boylston. Septic systems serving commercial and industrial establishments in the Shrewsbury Street-Hartwell Street area are likely sources of this problem. It is recommended that the town require biannual inspection of industrial and commercial sub-surface disposal systems and adopt and enforce a mandatory pumping frequency.

Worcester

No major water quality problems have been identified to be associated with the few remaining septic systems in the areas of the city within the Lake Quinsigamond drainage area. Areas where septic systems are still in use include a low section of Burncoat Street (north of East Mountain Street) and the Danvers Street area south of Sunderland Road. Where possible, homes should connect to the sewer system in accordance with the city's sewer use ordinance.

2. Sanitary Landfills

At the present time, there are no active landfill sites in the Lake Quinsigamond/Flint Pond drainage area. There are, however, two former landfills located within the basin. These include the former Shrewsbury landfill on North Quinsigamond Avenue and a private landfill on the grounds of the Worcester State Hospital.

The old Shrewsbury landfill was closed and sealed in accordance with approved plans and specifications in 1974. Monitoring of Billings Brook shows no indication of chemical or bacterial contamination attributable to the landfill. Monitoring data in fact, indicates significant improvement over data collected in 1971. Presently, Billings Brook meets the Class B criteria.

A private landfill located on the grounds at the Worcester State Hospital was ordered closed in the late 1960's due to severe rodent problems. Although it has been reported that the site is being used as a dump for construction and other non-organic solid wastes. Monitoring of the Medical School Drain, the drainage area in which the landfill is located, does not indicate any bacterial or other water quality problem attributable to the landfill. The regional office of DEQE is investigating the operational status of this facility.

3. Erosion - Sedimentation and Land Disturbing Activities

Any anthropogenic activity which takes place on the land surface and involves the disturbance and removal of topsoil and vegetation can be expected to result in the erosion of soil. Any such activity can therefore be considered a potential nonpoint pollution source. Activities which can be included in this category of nonpoint sources include construction activities (homes, malls, industries, highways, utilities, apartment and condominium complexes, etc.); agricultural operations (particularly cropland and pasture land); sand and gravel operations; stream channel modifications; forestry and other vegetation removal operations in addition to a variety of related activities. While many of these activities may appear temporary or; at worst, aesthetically unpleasant, they can all become significant nonpoint pollution sources during storm events due to the scouring effects of rainfall and runoff and to the variety and quantity of water-soluble substances that become mobile in stormwater runoff. The following sections list the various nonpoint sources identified in each community during the 314/NURP field investigations.

Boylston

No major erosion or construction related nonpoint sources were identified in Boylston. Two sand and gravel operations located in the

Morningdale section do not present any significant sources of pollution to the Lake or Newton Pond at this time. The town has adopted an earth removal by-law and established an Earth Removal Board. The board establishes guidelines for all earth-disturbing activities within the town to minimize erosion.

Grafton

With the exception of proposed industrial expansion along Creeper Hill Road and shoreline encroachment on Flint Pond, no major erosion, agricultural, or construction-related sources were identified. As indicated in the section on industrial discharges, industrial point and nonpoint sources have had and are continuing to have, a significant impact on Bonnie Brook and Flint Pond. These activities are also located in the Creeper Hill Road area. Problems include gravel parking and loading areas, open air storage of metals and other fabrication materials, on-site waste oil disposal and transportation related problems.

Millbury

No erosion, agriculture or construction-related nonpoint sources were identified within the area of Millbury tributary to Lake Quinsigamond and Flint Pond.

Shrewsbury

Nonpoint sources within this category identified in Shrewsbury include sand and gravel operations, an asphalt batching operation, industrial development, construction and streambank erosion.

Sand and gravel operations include the Worcester Sand and Gravel Company on Holden Street and the F & G Sand and Gravel Company on North Quinsigamond Avenue. Washing and transportation of gravel and sand at the Worcester Sand and Gravel Company has resulted in the deposition of an estimated 15,000 cubic yards of silt in the lake above Main Street, Shrewsbury. Problems identified at F & G in previous surveys (DWPC, 1971) appear to have been reduced or eliminated following the construction of an on-site sedimentation basin and the sealing of the town landfill. Water quality in Billings Brook reflects these improvements. Intense rainstorms have been observed to result in the suspension of fine silt both in the brook and in Eagle Head Cove. Although no major water quality problems were identified which could be directly attributed to it, the Henley-Lundgren Asphalt plant on the Southwest Cutoff was identified as a potential source of sediment in Flint Pond. Wind-induced erosion and transport of fine particles in addition to runoff-scoured materials and the transportation aspects of sand and gravel operations in general may represent a significant fraction of the sediment load to the lake.

Past development and uses of land surrounding the lower reach of Poor Farm Brook (from City Farm Pond to the Lake) have resulted in stream bank deterioration and erosion. Upstream from City Farm Pond, a dirt-bike trail system in the open, undeveloped tract of land between East Mountain Street and the Northwest Cutoff was identified as a small but potential source of eroded material into City Farm Pond.

West Boylston

One agricultural nonpoint source was identified in West Boylston. The Worcester County Jail operates a cattle farm on the site. Pasture land runs down to Poor Farm Brook just above the city line. When the cattle are allowed to graze near the brook, particularly in the spring when the ground is saturated, significant quantities of iron and paticulate matter are released from the soil and washed into the brook. No other major erosion or construction-related sources were identified.

Worcester

Several erosion-related problems areas were identified in Worcester. Problem areas in the Poor Farm Brook watershed include the following:

1. Vegetation and topsoil stripped area on steep slopes behind Quabbin Estates (off East Mountain Street); and
2. Severe erosion problems on southwest portion of City Farm Pond shoreline above and below Gareppy Plating.

A major contributing problem in the Coal Mine Brook watershed is the drainage swale between the westbound land of I-290 and the Lincoln Plaza shopping center. Continued dumping of dry fill,construction debris and ash as well as inadequate vegetative cover or other slope stabilization measures contribute to this problem area.

Sand application for snow and ice control appears to be the major source of sediment in the Medical School Drain. A similar situation exists at Belmont Street Drain.

Unimproved road surfaces, dumping of leaves and brush cuttings and modification in the wetland between Trahan and Ernest Avenues (which is the headwater area of Fitzgerald Brook) all contribute to the sediment and nutrient load. Similar dumping of leaves and brush in the swales on either side of the brook from Coburn Avenue to the lake further contribute to solids and nutrient loads.

A similar situation exists in the O'Hara Brook watershed . In addition to dumping of grass , brush cuttings and leaves on the stream banks, winter sand application and runoff from the railroad bed and open dump at the railroad siding behind Camosse Brothers all contribute to the pollution load of O'Hara Brook.

4. Stormwater Runoff

Urban stormwater runoff has long been recognized as a potential source of water pollution. Assessments of the magnitude and severity of the stormwater problem have been hampered in past efforts due to the higher priority placed on point source control/elimination and the limited,and usually inadequate, levels of funding made available to conduct such assessments. However, as point sources have generally been brought under control, and the impacts of stormwater runoff have become more apparent, the U.S. Environmental Protection Agency, under Congressional order, undertook a systematic assessment of the nature and magnitude of the stormwater runoff problem on a nationwide basis. The program, entitled the Nationwide Urban Runoff Program (NURP), funded twenty-eight individual stormwater-related projects in different areas of the country. The assessment of the magnitude and severity of the stormwater pollution load to Lake Quinsigamond/Flint Pond is one of those projects.

The work plan developed to perform this assessment included stormwater sampling, runoff modeling, receiving water quality modeling and the development of a recommended control strategy. The consultant firm of Environmental Design and Planning Inc. was hired to conduct the required field studies including flow gaging, rain gaging and stormwater sampling as well as runoff modeling. Meta Systems was hired as a subconsultant to perform receiving water impact analysis including the development and application of appropriate water quality models. The following sections summarize the activities and conclusions of the NURP program for Lake Quinsigamond.

a. Stormwater Sampling Program

Stormwater flows and water quality samples were monitored at six primary sampling sites during the summer and fall of 1980. The flows were measured with continuous recording charts. Discrete water quality samples were taken over the course of rain events to enable precise tracking of loading variations with flows. Settling column samples were also taken at selected sites (Belmont Street drain and Fitzgerald Brook) to better assess the settling potential of water quality constituents.

Figure III-2 designates the locations of these sampling stations. The stations are as follows:

Station Name	Tributary Name	Code
Jordan Pond	Inlet to Jordan Pond	P1
Route 9	Belmont Street Storm drain	P2
Locust St.	Tributary to Belmont St.drain	P3
Anna St.	Fitzgerald Brook	P4
Convent	Tributary to Coal Mine Brook	P5
Tilly Brook	Tilly Brook	P6

Water quality samples were taken at the primary stations using

LAKE QUINSIGAMOND
NURP PRIMARY STORMWATER SAMPLING STATIONS

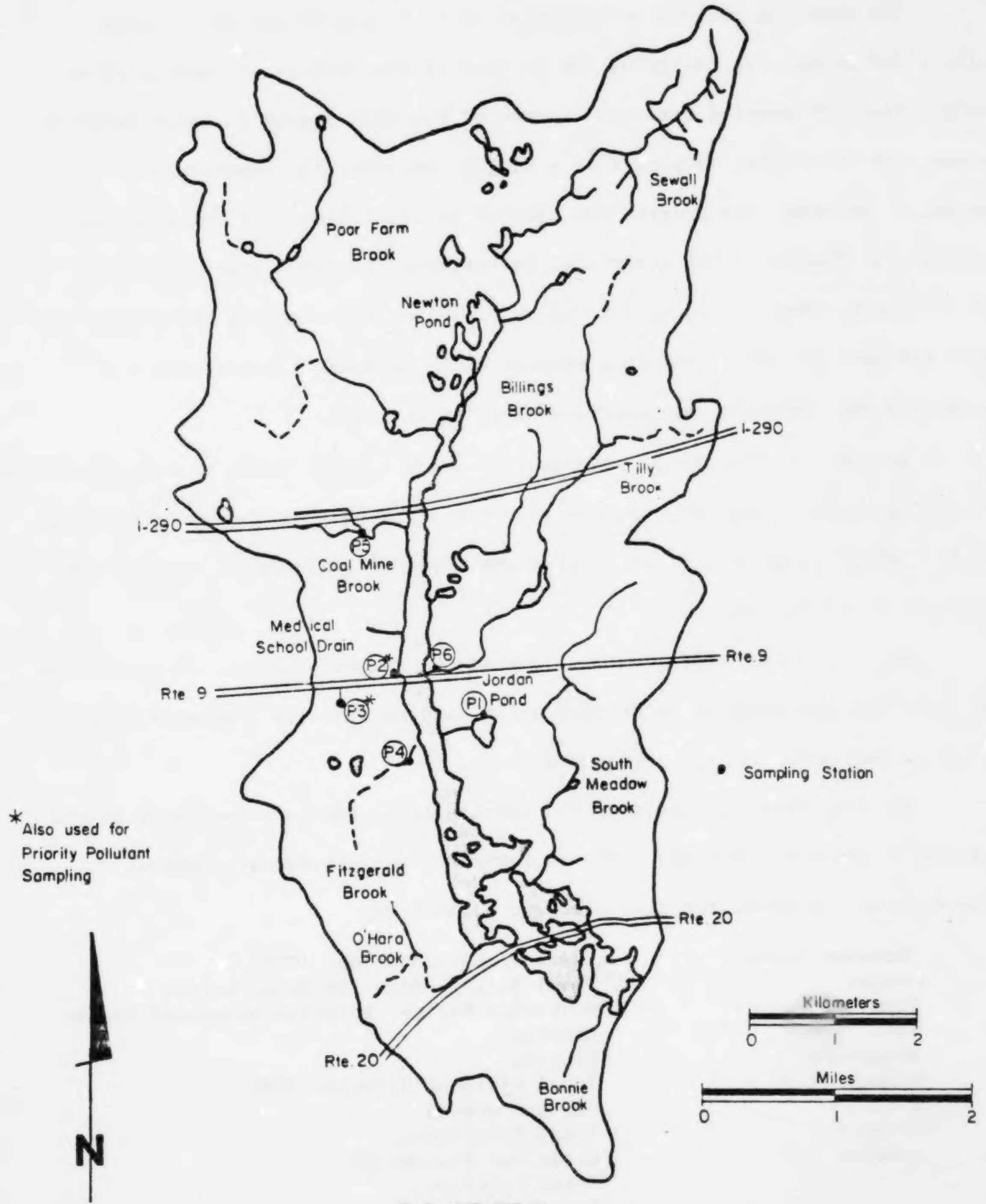

Sewall Brook
Poor Farm Brook
Newton Pond
Billings Brook
I-290
Tilly Brook
I-290
P5
Coal Mine Brook
Medical School Drain
P2*
P6
Rte. 9
Rte 9
Jordan Pond
P3*
P1
P4
South Meadow Brook
• Sampling Station
*Also used for Priority Pollutant Sampling
Fitzgerald Brook
Rte. 20
O'Hara Brook
Kilometers
0
1
2
Miles
0
1
2
Rte. 20
Bonnie Brook
N

FIGURE III-2

Manning automatic samplers collecting discrete and sequential samples over a specified period of time. Samplers were set to initiate sampling at the first significant increase in flow caused by storm runoff. In most cases the first samples were taken within a few minutes of the first stormwater flow.

The sampling program was designed to provide coverage of 23 water quality indicators. In designing the program it was considered imperative to analyze discrete samples over the course of two rain events whenever possible rather than to combine samples into a single composite for laboratory analysis. However, the program was limited by the capacity of the Lawrence Experimental Station (LES) analytical laboratory. To avoid overloading the lab a rotating program was used to allow full discrete sampling coverage of all sites for some events. Composite samples would be taken for stations and parameters not scheduled for discrete sampling analysis.

At any one time in the program five water quality samplers were operational. The site at the Convent (P5) covered only the first part of the program (through August, 1980). Subsequently the sampler was moved to Tilly Brook (P6) for the remainder of the program.

For all sample splitting and compositing a cone splitter was used. The cone splitter was designed to produce split samples that are representative of both flow and water quality parameters.

The laboratory analysis of the samples collected were performed by the Lawrence Experimental Station (LES) in Lawrence, Massachusetts. Samples collected were analyzed for the following parameters:

Chromium (total)
Copper
Iron
Lead
Manganese
Nickel
Zinc
Arsenic
Cadmium

Chemical Oxygen Demand (COD)
Total Solids, Volatile Total Solids
Suspended Solids, Volatile Suspended Solids
Ammonia
Nitrate
Total Kjeldahl Nitrogen (TKN)
Oil and Grease
Total Phosphorus
Dissolved Phosphorus
Total Coliform
Fecal Coliform

Stormwater Data Summaries

Mass pollutant loads and average pollutant concentrations were calculated as per the above procedures. Tables III-1 through III-6 present the results. TableIII-7 presents the peak water quality concentrations. Mass loads are for storm events as defined previously. Loads are reported in pounds, average concentrations are reported in mg/l.

The lack of a distinguishable draw down curve precluded calculation of mass loading at Tilly Brook. Average concentrations were determined over the period sampled.

In the following tables the numbers in parenthesis represent field-composited data. The other numbers represent discrete samples that were analyzed through the procedures for multiple samples previously discussed.

Settling Column Tests

Accurate determination of settling characteristics of urban runoff is important for the rational design of solids separating devices. Since eutrophication of the Lake is a major issue, the effectiveness of solids separating devices will also depend upon the partitioning of nutrients (especially, phosphorus) between the dissolved and suspended fractions. A state-of-the-art settling column was developed by EDP in order to obtain an accurate measurement of each fraction. Settling column tests were performed on samples collected at Route 9 and Anna Street in late November and early December, 1980.

The settling column test provides an accurate link between settling rates and pollution parameters. For each run on a 30 gallon stormwater sample, 3 points on the column are monitored. At the initial time, after mixing, the three samples were assumed to have fully mixed conditions and analytical results generally supported this assumption. Subsequent samples contain only those solids with settling rates too slow to cover the distance between the column top and the sampling point. Samples were analyzed for both solids and nutrients.

TABLE III-1

Water Quality Summaries

Location: Jordan Pond

Code : Pl

Date	TSS		VSS		TS		TVS	
	pounds	ave. mg/l	pounds	ave. mg/l	pounds	ave. mg/l	pounds	ave. mg/l
6/29	350	32	155	14	3200	292	990	90
7/ 8	290	57	59	12	950	188	240	48
7/17	390	122	77	24	680	216	210	66
7/29	75	7.6	9	0.9	884	89	304	30
8/ 2	26	26	11	11	200	202	89	90
8/ 3	79	42	20	11	210	110	53	28
8/11	5	8.4	2	3.3	180	300	130	214
9/10	9	39	3	13	41	178	12	52
9/18	676	324	110	53	860	410	156	75

	COD		TKN		NO_3-N		NH_3-N	
Date	total pounds	ave. mg/l	total pounds	ave mg/l	total pounds	ave mg/l	total pounds	ave mg/l
6/29	1700	150	20.3	1.9	15.0	1.4	3.6	0.32
7/ 8	240	48	5.6	1.1	3.0	0.59	0.6	0.13
7/17	270	85	7.0	2.2	3.7	1.19	0.16	0.051
7/29	623	62	4.1	0.41	5.9	0.59	0.54	0.054
8/ 2	63	64	1.7	1.73	1.4	1.44	0.32	0.33
8/ 3	50	26	1.5	0.81	1.6	0.83	0.19	0.10
8/11	(38)	(64)	(0.4)	(0.73)	(1.3)	(2.2)	(0.09)	(0.15)
9/10	23	100	(0.39)	(1.7)	(0.49)	(2.1)	(0.09)	(0.40)
9/17	200	96	(3.1)	(1.5)	(1.6)	(0.7)	(0.21)	(0.10)

TABLE III-1(cont)

	Dissolved P		Total P		Ortho-phosphate		Dissolved ortho phos.	
Date	Total Pounds	Ave mg/1	Total Pounds	Ave mg/1	Total Pounds	Ave mg/1	Total Pounds	Ave mg/1
6/29	-	-	2.3	0.2	1.48	0.13	0.36	0.03
7/ 8	0.38	0.075	1.18	0.23	-	-	-	-
7/17	1.45	0.46	4.97	1.58	-	-	-	-
7/29	4.21	0.42	5.67	0.56	-	-	-	-
8/ 2	0.05	0.05	0.15	0.15	-	-	-	-
8/ 3	0.24	0.13	0.52	0.28	-	-	-	-
8/11	(0.02)	(0.04)	(0.04)	(0.06)	-	-	-	-
9/10	(0.014)	(0.06)	(0.035)	(0.15)	-	-	-	-
9/17	(0.31)	(0.15)	(1.0)	(0.48)	-	-	-	-

	Cd		Cr		Cu		Pb		Fe	
Date	Total Pounds	Ave. mg/1	Total Pounds	Ave. mg/1	Total Pounds	Ave. mg/1	Total Pounds	Ave. mg/1	Total Pounds	Ave. mg/1
6/29	0.087	0.008	0.012	0.001	0.78	0.071	1.29	0.117	9.6	0.871
7/ 8	0.054	0.011	0.025	0.005	0.31	0.061	1.10	0.217	13.6	2.96
7/17	0.011	0.003	0.012	0.004	0.25	0.079	0.90	0.29	10.4	3.31
7/29		(0.00)		(0.00)	(0.49)	(0.05)	(1.2)	(0.12)	20.1	(2.1)
8/ 2	0.003	0.003	0.003	0.003	0.055	0.056	0.152	0.15	0.84	0.85
8/ 3	0.003	0.002	0.002	0.001	0.15	0.079	0.25	0.13	2.8	1.48
8/11		(0.00)		(0.00)	(0.22)	(0.37)	(0.086)	(0.15)	(0.46)	(0.78)
9/10		(0.00)		(0.00)	(0.023)	(0.10)	(0.03)	(0.13)	(0.17)	(0.75)
9/17		(0.00)		(0.00)	(0.19)	(0.09)	(0.42)	(0.20)	(5.2)	(2.5)

	Mn		Ni		Zn		As	
Date	Total pounds	Ave. mg/1	Total Pounds	Ave. mg/1	Total Pounds	Ave mg/1	Total Pounds	Ave. mg/1
6/29	3.89	0.35	-	-	1.97	0.18	0.046	0.004
7/ 8	2.09	0.41	0.37	0.073	1.11	0.22	0.043	0.009
7/17	1.72	0.55	0.044	0.014	0.65	0.21	0.003	0.001
7/29	(2.28)	(0.23)	(0.20)	(0.02)	(0.96)	(0.14)	(0.059)	(0.006)
8/ 2	0.273	0.28	0.002	0.002	0.16	0.16	0.006	0.006
8/ 3	0.48	0.25	0.021	0.011	0.46	0.24	0.01	0.005
8/11	(0.14)	(0.24)		(0.00)	(0.158)	(0.27)	(0.002)	(0.003)
9/10	(0.058)	(0.25)	(0.005)	(0.02)	(0.081)	(0.35)	(0.001)	(0.003)
9/17	(0.73)	(0.35)		(0.00)	(0.40)	(0.19)	(0.021)	(0.01)

TABLE III-2

Water Quality Summaries

Location: Rt. 9

Code: P2

	TSS		VSS		TS		TVS	
Date	Pounds	Ave. mg/l	Pounds	Ave. mg/l	Pounds	Ave. mg/l	Pounds	Ave. mg/l
7/17	4800	600	690	86	5700	706	710	88
7/29	2800	118	560	24	5500	239	1500	66
8/ 2	132	80	37	22	366	222	84	51
8/ 3	1000	231	120	27	1400	317	215	50
8/11	21	18	7	5.9	342	288	86	73
9/10	54	110	12	24	172	349	32	65
9/18	12200	790	1400	87	13600	880	1800	116

	COD		TKN		NO_3-N		NH_3-N	
Date	Total Pounds	Ave. mg/l	Total pounds	Ave. mg/l	Total pounds	Ave. mg/l	Total pounds	Ave. mg/l
7/17	810	101	(10.5)	(1.3)	-	-	-	-
7/29	-	-	-	-	-	-	-	-
8/ 2	129	78	(3.3)	(2.0)	(2.3)	(1.4)	(0.59)	(0.36)
8/ 3	143	33	(6.9)	(1.6)	(8.2)	(1.9)	(0.34)	(0.08)
8/11	79	67	(1.2)	(1.0)	(2.4)	(2.0)	(0.37)	(0.31)
9/10	88	178	2.1	4.3	1.3	2.6	0.08	0.16
9/18	2400	154	43.2	2.8	12.2	0.79	4.0	0.26

Date	Dissolved P		Total P		Orthophosphate		dissolved ortho phos.	
	Total Pounds	Ave. mg/l	Total Pounds	Ave. mg/l	Total Pounds	Ave. mg/l	Total Pounds	Ave. mg/l
7/17	(1.1)	(0.14)	(10.3)	(1.28)	-	-	-	-
7/29	-	-	-	-	-	-	-	-
8/ 2	(0.25)	(0.15)	(0.94)	(0.57)	-	-	-	-
8/ 3	(0.39)	(0.09)	(2.16)	(0.50)	-	-	-	-
8/11	(0.036)	(0.03)	(0.31)	(0.26)	-	-	-	-
9/10	0.08	0.16	0.83	1.68	-	-	-	-
9/18	3.89	0.25	24.5	1.59	-	-	-	-

TABLE III-2 (cont)

Date	Cd Total Pounds	Cd Ave. mg/l	Cr Total Pounds	Cr Ave. mg/l	Cu Total Pounds	Cu Ave. mg/l	Pb Total Pounds	Pb Ave. mg/l	Fe Total Pounds	Fe Ave. mg/l
7/17		(0.00)		(0.00)	(0.89)	(0.11)	(2.7)	(0.33)	(20.9)	(2.6)
7/29	0.12	0.005	0.007	0.0003	2.65	0.12	9.28	0.40	194	8.4
8/ 2		(0.00)		(0.00)	(0.066)	(0.04)	(0.12)	(0.07)	(1.5)	(0.92)
8/ 3		(0.00)		(0.00)	(0.47)	(0.11)	(1.51)	(0.35)	(10.4)	(2.4)
8/11		(0.00)		(0.00)	(0.095)	(0.08)	(0.18)	(0.15)	(2.0)	(1.7)
9/10		0.00		0.00	0.065	0.13	0.34	0.69	4.7	9.5
9/18		(0.00)		(0.00)	2.6	0.17	11.8	0.77	146	9.5

Date	Mn Total pounds	Mn Ave. mg/l	Ni Total pounds	Ni Ave. mg/l	Zn Total pounds	Zn Ave. mg/l	As Total pounds	As Ave. mg/l
7/17	(3.5)	(0.43)	(0.08)	(0.01)	(1.7)	(0.21)	(0.08)	(0.01)
7/29	8.4	0.36	0.35	0.015	8.1	0.35	0.48	0.021
8/ 2	(0.63)	(0.38)	(0.03)	(0.02)	(0.20)	(0.12)	(0.007)	(0.004)
8/ 3	(0.91)	(0.21)	(0.09)	(0.02)	(0.87)	(0.20)	(0.043)	(0.01)
8/11	(0.53)	(0.45)	(0.23)	(0.00)	(0.23)	(0.19)	(0.011)	(0.009)
9/10	0.27	0.55	0.001	0.002	0.2	0.41	0.013	0.026
9/18	9.2	0.60		0.00	3.2	0.21	0.16	0.010

TABLE III-3

Water Quality Summaries

Location: Locust St.

Code : P3

	TSS		VSS		TS		TVS	
Date	Pounds	Ave mg/l	Pounds	Ave. mg/l	Pounds	Ave. mg/l	Pounds	Ave. mg/l
7/17	4800	735	450	70	5600	852	620	95
8/ 2	44	69	15	23	150	233	38	59
8/11	10	47	3	14	71	335	41	193
9/10	49	78	14	22	156	248	41	65
9/18	4600	441	830	79	6500	622	1350	128
9/26	160	53	64	21	480	161	180	60

	COD		TKN		NO_3-N		NH_3-N	
Date	Total Pounds	Ave. mg/l	Total pounds	Ave. mg/l	Total pounds	Ave. mg/l	Total pounds	Ave. mg/l
7/17	620	95	(15.6)	(2.4)	-	-	-	-
8/ 2	41	64	1.6	2.5	1.0	1.6	0.39	0.61
8/11	14	66	0.28	1.3	0.38	1.8	0.07	0.33
9/10	69	109	(2.1)	(3.3)	(2.0)	(3.2)	(0.02)	(0.03)
9/18	2100	204	39	3.7	6.7	0.64	3.4	0.32
9/26	245	81	8.1	2.7	2.8	0.93	8.0	2.7

	Dissolved P		Total P		Ortho-phosphate		dissolved ortho-phos	
Date	Total pounds	Ave. mg/l	Total pounds	Ave. mg/l	Total pounds	Ave. mg/l	Total pounds	Ave. mg/l
7/17	(1.0)	(0.16)	(10.4)	(1.60)	-	-	-	-
8/ 2	0.08	0.12	0.31	0.48	-	-	-	-
8/11	0.02	0.094	0.08	0.38	-	-	-	-
9/10	(0.14)	(0.22)	(0.69)	(1.1)	-	-	-	-
9/18	2.3	0.22	24.2	2.3	-	-	-	-
9/26	0.81	0.27	3.3	1.1	-	-	-	-

TABLE III-3 (cont)

Date	Cd		Cr		Cu		Pb		Fe	
	Total pounds	Ave. mg/l	Total pounds	Ave. mg/l	Total pounds	Ave. mg/l	Total pounds	Ave. mg/l	Total pounds	Ave. mg/l
7/17	(0.13)	(0.02)	(0.07)	(0.01)	(0.65)	(0.10)	(2.3)	(0.35)	(22)	(3.4)
8/ 2	0.05	0.08		0.00	0.073	0.11	0.12	0.19	1.16	1.8
8/11		0.00		0.00	0.018	0.085	0.034	0.16	0.24	1.1
9/10		(0.00)		(0.00)	(0.06)	(0.10)	(0.08)	(0.13)	(0.47)	(0.75)
9/18		0.00		0.00	1.7	0.16	6.6	0.63	130	12.4
9/26		0.00	0.002	0.001	0.26	0.086	0.46	0.15	7.2	2.4

Date	Mn		Ni		Zn		As	
	Total pounds	Ave. mg/l	Total pounds	Ave. mg/l	Total pounds	Ave. mg/l	Total pounds	Ave. mg/l
7/17	(2.3)	(0.35)	(0.07)	(0.01)	(1.4)	(0.22)		(0.000)
8/ 2	0.16	0.25	0.007	0.01	0.187	0.29	0.003	0.005
8/11	0.042	0.20	0.003	0.014	0.033	0.16	0.001	0.005
9/10	(0.16)	(0.25)	(0.013)	(0.02)	(0.22)	(0.35)	(0.002)	(0.003)
9/18	6.0	0.57		0.00	2.8	0.27	0.16	0.015
9/26	0.77	0.26	0.043	0.014	0.55	0.18	0.025	0.008

TABLE III-4

Water Quality Summaries

Location: Anna Street

Code: P4

Date	TSS pounds	TSS ave. mg/l	VSS pounds	VSS ave. mg/l	TS pounds	TS ave. mg/l	TVS pounds	TVS ave. mg/l
6/16	3000	168	870	50	4100	237	1600	89
6/29	1800	47	590	16	5100	136	1500	41
7/16	2800	320	450	52	4000	460	530	61
8/ 2	660	58	215	19	2100	185	495	44
8/ 3	930	106	150	17	1980	227	340	39
8/11	135	12	46	4	2700	238	1700	150
9/10	5	14	1	3	74	208	14	39
9/18	6600	500	850	64	7400	565	1200	88
9/26*	1000	19	500	11	8500	159	3100	58

Date	COD Total pounds	COD ave. mg/l	TKN total pounds	TKN ave. mg/l	NO_3-N total pounds	NO_3-N ave. mg/l	NH_3-N total pounds	NH_3-N ave. mg/l
6/16	2800	162	35.3	2.0	14.1	0.81	0.5	0.03
6/29	3400	92	(96)	(2.6)	(22.3)	(0.6)	(0.0)	(0.00)
7/17	900	104	23.9	2.8	9.6	1.11	0.68	0.08
8/ 2	530	47	16.2	1.4	12.8	1.14	0.97	0.09
8/11	515	45	5.8	0.5	21.3	1.87	1.16	0.10
9/10	22	62	0.4	1.1	0.9	2.5	0.00	0.01
9/18	1400	104	(31.6)	(2.4)	(10.5)	(0.8)	(1.71)	(0.13)
9/26*	2800	53	110	(2.0)	48	(0.9)	5.9	(0.11)

Date	Dissolved P Total pounds	Dissolved P Ave. mg/l	Total P total pounds	Total P ave mg/l	Ortho-phosphate total pounds	Ortho-phosphate ave mg/l	dissolved ortho-phos total pounds	dissolved ortho-phos ave mg/l
6/16	-	-	9.8	0.56	2.46	0.14	0.58	0.03
6/29	-	-	(24.6)	(0.66)	(16.7)	(0.45)	(24.6)	(0.66)
7/17	1.57	0.18	13.9	1.61	-	-	-	-
8/2	0.77	0.07	2.23	0.20	-	-	-	-
8/11	0.61	0.05	1.12	0.10	-	-	-	-

TABLE III-4(cont)

Date	Dissolved P total pounds	 ave. mg/l	Total P total pounds	 ave. mg/l	Orthophosphate total pounds	 ave. mg/l	Dissolved ortho-phos total pounds	 ave. mg/l
9/10	0.06	0.17	0.11	0.31	-	-	-	-
9/18	(3.16)	(0.24)	(10.5)	(0.80)	-	-	-	-
9/26*	(8.5)	(0.16)	(25)	(0.46)	-	-	-	-

Date	Cd total pounds	 ave. mg/l	Cr total pounds	 ave. mg/l	Cu total pounds	 ave. mg/l	Pb total pounds	 ave. mg/l	Fe total pounds	 ave mg/l
6/29		(0)	(.37)	(,01)	(2.98)	(.08)	(11.2)	(0.3)	(78.1)	(2.1)
7/17	.025	.029	.016	.019	1.45	.170	3.6	.420	28.4	3.3
8/ 2	.022	.019	.084	.075	0.73	.064	1.1	.094	7.8	.687
8/11	-	-	-	-	0.28	.024	0.27	.024	1.5	.127
9/10		0.00		0.00	0.017	.048	0.041	.115	0.39	1.096
9/18		(0.00)		(0.00)		(.04	(0.53)	(000)	(1.32)	(0.10)
9/26*		(0.00)		(0.00)	(3.7)	(.07)	(8.5)	(.16)	(75)	(1.4)

Date	Mn total pounds	 ave. mg/l	Ni total pounds	 ave. mg/l	Zn total pounds	 ave. mg/l	As total pounds	 ave. mg/l
6/29	(10.4)	(.280)	-	-	(7.1)	(.190)	(0.52)	(.014)
7/17	2.4	.280	0.12	.014	2.6	.300	0.04	.047
8/ 2	0.7	.065	0.11	.098	2.1	.190	0.06	.059
8/11	0.2	.014	-	-	0.3	.024	0.002	.002
9/10	.04	.112		(0.00)	.03	.084	.002	.056
9/18	(.26)	(0.02)		(0.00)	(.79)	(0.06)	(.01)	(0.001)
9/26*	(8.5)	(0.16)	(2.1)	(0.04)	22.0	(0.41)	(0.27)	(0.005)

* prestorm flow sampled

TABLE III-5

Water Quality Summaries

Location: Convent

Code : P5

Date	TSS pounds	TSS ave. mg/l	VSS pounds	VSS ave. mg/l	TS pounds	TS ave. mg/l	TVS pounds	TVS ave. mg/l
6/20	46	19	18	7.6	340	143	110	46
6/29	294	21	202	14.6	2459	178	553	40
7/ 8	163	79	35	17	428	207	93	45
7/17	215	122	33	19	400	227	110	62
7/29	655	42	230	15	2300	147	800	51
8/ 2	36	17	13	6.1	640	302	200	93
8/ 3	460	56	83	10	1790	218	210	26
8/11	20	3.7	13	2.4	1320	240	900	165

Date	COD Total pounds	COD ave. mg/l	TKN Total pounds	TKN ave. mg/l	NO_3-N Total pounds	NO_3-N ave. mg/l	NH_3-N Total pounds	NH_3-N ave. mg/l
6/20	110	46	1.4	0.59		-		-
6/29	2040	148	21.2	1.5	11.5	0.83	4.5	0.32
7/ 8	121	59	(2.1)	(1.0)		(0.00)	(0.29)	(0.14)
7/17	84	48	2.6	1.5	1.56	0.88	0.12	0.068
7/29	1200	77	16.9	1.1	12.1	0.77	1.0	0.064
8/ 2	(245)	(115)	(3.8)	(1.8)	(2.8)	(1.3)	(0.49)	(0.23)
8/ 3	210	25	3.2	0.39	4.1	0.50	0.31	0.038
8/11	250	45	2.5	0.46	7.6	1.4	0.29	0.053

Date	Dissolved P Total pounds	Dissolved P ave. mg/l	Total P Total pounds	Total P ave. mg/l	Ortho-phosphate Total pounds	Ortho-phosphate ave. mg/l	Dissolved ortho-phos Total pounds	Dissolved ortho-phos ave. mg/l
6/20		-	0.17	0.07		-		-
6/29		-	1.85	0.13	1.71	0.12	0.69	0.050
7/ 8	(0.06)	(0.03)	(0.52)	(0.25)		-		-
7/17	0.10	0.057	2.49	1.41		-		-

TABLE III-5 (cont'd)

Date	Dissolved P Total pounds	Dissolved P ave. mg/l	Total P Total pounds	Total P ave. mg/l	Ortho-phosphate Total pounds	Ortho-phosphate ave. mg/l	Dissolved ortho-phos Total pounds	Dissolved ortho-phos ave. mg/l
7/29	8.8	0.56	18.1	1.16		-		-
8/ 2	(0.064)	(0.03)	(0.23)	(0.11)		-		-
8/ 3	0.20	0.024	1.67	0.20		-		-
8/11	0.14	0.026	0.22	0.04		-		-

Date	Cd Total pounds	Cd ave. mg/l	Cr Total pounds	Cr ave. mg/l	Cu Total pounds	Cu ave. mg/l	Pb Total pounds	Pb ave. mg/l	Fe Total pounds	Fe ave. mg/l
6/29	0.06	0.004	8.12	0.59	2.1	0.15	3.29	0.24	64.6	4.68
7/ 8	(0.02)	(0.01)	(0.06)	(0.03)	(0.12)	(0.06)	(0.49)	(0.24)	(2.1)	(1.0)
7/17	0.006	0.003	1.17	0.66	0.27	0.15	0.67	0.38	4.06	2.3
7/29		0.00	2.56	0.16	1.99	0.13	3.58	0.23	40.2	2.6
8/ 2		(0.0)		(0.0)	(0.21)	(0.10)	(0.13)	(0.06)	(0.70)	(0.33)
8/ 3	0.049	0.006	0.045	0.005	0.48	0.058	0.59	0.072	10.7	1.3
8/11		0.00		0.00	0.41	0.075	0.31	0.057	1.78	0.33

Date	Mn Total pounds	Mn ave. mg/l	Ni Total pounds	Ni ave. mg/l	Zn Total pounds	Zn ave. mg/l	As Total pounds	As ave. mg/l
6/29	12.8	0.93	0.33	0.024	5.1	0.37	0.22	0.016
7/ 8	(0.75)	(0.36)	(0.21)	(0.10)	(0.25)	(0.12)		(0.000)
7/17	0.92	0.52	0.003	0.002	0.44	0.25	0.006	0.003
7/29	13.7	0.88	0.18	0.012	3.6	0.23	0.23	0.015
8/ 2	(0.45)	(0.21)		(0.00)	(0.30)	(0.14)	(0.009)	(0.004)
8/ 3	1.8	0.22	0.007	0.001	1.58	0.19	0.066	0.008
8/11	1.1	0.20		0.00	0.39	0.071	0.013	0.002

TABLE III-6

Water Quality Summaries

Location: Tilly Brook

Code: P6

Date	TSS		VSS		TS		TVS	
	pounds	ave. mg/l	pounds	ave. mg/l	pounds	ave. mg/l	pounds	ave. mg/l
9/10		33		15		145		45
9/18		249		41		277		59
11/28		5.6		2.4		94		12
12/3		2.6		1.5		55		12
12/10		1.2		1.0		46		6

Date	COD		TKN		NO_3-N		NH_3-N	
	Total pounds	ave. mg/l	Total pounds	ave. mg/l	Total pounds	ave. mg/l	Total pounds	ave. mg/l
9/10		118		2.7		2.6		0.9
9/18		99		1.8		0.45		0.10
11/28		22		0.38		0.052		0.077
12/3		15		0.29		0.13		0.003
12/10		15		0.21		0.042		0.008

Date	Dissolved P		Total P		Ortho-phosphate		dissolved ortho-phos	
	total pounds	ave. mg/l	total pounds	ave. mg/l	total pounds	ave. mg/l	total pounds	ave. mg/l
9/10		0.45		0.78				
9/18		0.19		0.75				
11/28		0.021		0.052				
12/3		0.035		0.036				
12/10		0.014		0.024				

Date	Cd		Cr		Cu		Pb		Fe	
	total pounds	ave. mg/l	total pounds	ave. mg/l	total pounds	ave. mg/l	total pounds	ave. mg/l	total pounds	ave. mg/l
9/10		0.00		0.00		0.08		0.33		1.4
9/18		0.00		0.00		0.05		0.39		2.9
11/28		-		-		-		-		-
12/3		0.00		0.00		0.017		0.00		0.27
12/10		0.00		0.00		0.004		0.00		0.081

TABLE III-6 (cont'd)

Date	Mn		Ni		Zn		As	
	total pounds	ave. mg/l	total pounds	ave. mg/l	total pounds	ave. mg/l	total pounds	ave. mg/l
9/10		0.20		0.00		0.36		0.010
9/18		0.20		0.00		0.21		0.006
11/28		-		-		-		-
12/3		0.038		0.00		0.018		0.00
12/10		0.008		0.00		0.007		0.00

TABLE III-7

Peak Concentrations

Date	TS mg/l	TVS mg/l	TSS mg/l	VSS mg/l	TP mg/l	DIS.P mg/l	TKN mg/l	NH$_3$-N mg/l	NO$_3$-N mg/l	COD mg/l
Location: Jordan Pd.										
6/29	370	118	85	26	0.30	*	2.3	0.69	1.5	*
7/ 8	280	57	190	29	0.29	0.14	1.3	0.22	0.8	59
7/17	394	93	341	52	2.88	0.74	4.8	0.09	1.4	125
7/29	210	41	85	18	0.84	0.44	0.72	0.08	0.6	89
8/ 2	1100	650	139	27	0.43	0.14	3.2	0.36	2.4	86
8/ 3	220	46	120	21	0.56	0.18	1.4	0.30	1.4	72
(c)8/11	352	224	20	6	0.06	0.04	0.73	0.15	2.2	64
(c)9/10	270	70	81	32	0.15	0.06	1.7	0.40	2.1	117
(c)9/18	700	110	540	88	0.48	0.15	1.5	0.10	0.7	160
Location: Rte. 9										
(c)7/17	1042	122	897	122	1.28	0.14	1.3	*	*	197
7/29	570	220	330	76	*	*	*	*	*	*
(c)8/ 2	320	87	195	53	0.57	0.15	2.0	0.36	1.4	100
(c)8/ 3	420	60	350	37	0.50	0.09	1.6	0.08	1.9	82
(c)8/11	475	265	216	55	0.26	0.03	1.0	0.31	2.0	64
9/10	580	110	170	42	2.5	0.20	5.0	1.0	3.9	303
9/18	1200	240	1100	180	2.4	0.31	4.8	1.3	0.9	290
(s)11/28	168	48	58	16	0.38	0.16	1.5	0.11	1.6	69
(s)12/3	208	66	71	24	0.36	0.13	1.5	0.36	1.6	114
Location: Locust St.										
(c)7/17	1292	142	955	86	1.60	0.16	2.4	*	*	173
8/ 2	460	100	177	48	0.73	0.15	3.0	0.65	1.8	77
8/11	375	230	67	20	0.54	0.16	1.6	0.37	2.0	73
(c)9/10	450	130	190	48	1.1	0.22	3.3	0.03	3.2	160
9/18	1700	150	1600	140	3.2	0.40	4.4	0.42	1.0	250
9/26	334	106	314	54	5.9	0.44	5.2	0.40	1.1	181
Location: Fitzgerald Bk @ Anna St										
6/16	286	110	246	59	0.79	*	2.7	0.26	1.3	220
6/29	538	76	370	104	0.66	*	2.6	0.00	0.6	192
7/17	735	140	528	90	2.0	0.21	3.6	0.16	1.4	182

TABLE III-7 (cont'd)

Date	TS mg/l	TVS mg/l	TSS mg/l	VSS mg/l	TP mg/l	DIS.P mg/l	TKN mg/l	NH_3-N mg/l	NO_3-N mg/l	COD mg/l
Location: Fitzgerald Bk @ Anna St (cont)										
8/ 2	460	80	375	67	0.55	0.13	2.5	0.19	1.3	86
8/ 3	570	95	340	40	*	*	*	*	*	29
8/11	310	160	32	6.5	0.12	0.08	1.2	0.13	1.9	63
9/10	380	66	140	60	0.47	0.22	2.2	0.02	3.3	93
(c)9/18	1200	140	1100	122	0.80	0.24	2.4	0.13	0.8	160
(c)9/26	276	96	144	52	0.46	0.16	2.0	0.11	0.9	113
(s)11/28	260	82	115	22	0.38	0.16	2.2	0.15	2.6	69
(s)12/3	190	58	34	21	0.19	0.11	1.2	0.43	1.4	88
Location: Coal Mine Brk @ Convent										
6/20	812	*	158	62	0.31	*	2.0	*	*	140
6/29	680	143	132	44	0.21	*	4.2	1.0	1.3	261
(c)7/8	550	130	260	99	0.25	0.03	1.0	0.14	0.0	162
7/17	536	118	271	49	2.0	0.06	3.9	0.13	1.0	53
7/29	560	120	190	55	1.56	1.0	4.3	0.12	0.9	140
(c)8/2	420	110	55	46	0.11	0.03	1.8	0.23	1.3	115
8/3	400	62	46	18	0.24	0.04	0.76	0.11	1.3	58
8/11	442	236	13	7	0.09	0.04	0.87	0.08	2.9	86
Location: Tilly Bk										
9/10	210	88	83	34	0.95	0.58	3.7	1.7	3.9	210
9/18	700	200	570	120	1.7	0.24	4.4	0.17	0.5	450
11/28	180	30	77	6	0.16	0.04	1.0	0.12	0.1	39
12/3	112	26	11	6	0.08	0.08	0.51	0.02	0.5	31
12/10	114	22	4	4	0.07	0.05	0.73	0.05	0.1	43

(c) - Nutrient concentrations from one flow composite

(s) - All concentrations from settlability test

The data was plotted as the percent of the water quality constituent remaining versus the settling velocity. Initial concentrations were determined by three samples well spaced over the column. Average initial concentrations are presented in Table III-8.

Discussion

Primary indicators of pollutant settling potential are the settling column results for suspended solids. Tests on samples collected at both Route 9 and Anna Street show moderate amounts of suspended solids that will readily settle. At Route 9 approximately 80% of the suspended solids have settling velocities less than 0.1 cm per second. Approximately 40% of the suspended solids have settling velocities less than 0.001 cm per second at Route 9. At Anna Street, approximately 50% of the suspended solids have settling velocities less than 0.1 cm per second. Approximately 30% have velocities less than 0.001 cm per second.

Volatile suspended solids at both stations showed signs of significant settling over the range of settling velocities examined. At Route 9 approximately 80% of volatile suspended solids have settling velocities lower than 0.1 cm per second. At Anna Street 50% of volatile suspended solids had settling velocities lower than 0.1 cm per second for one storm, and 80% were lower than 0.1 cm per second for the other storm. Total volatile solids did not settle suggesting that only a small portion of the organic solids are readily settleable solids. However, a significant portion of organics that are suspended solids will settle.

Most nutrients followed closely the results of volatile suspended solids as might be expected. TKN and TP showed portions (less than 20%) tied-up with readily settleable solids. Dissolved phosphorus.NO_3-N and NH_3-N showed no signs of settling. COD showed greater settling potential with something less than 40% remaining in solids with settling velocities less than 0.01 cm/sec. Nutrient samples at both Route 9 and Anna Street behaved similarly.

TABLE III-8

Settling Column Initial Concentrations (mg/l)

	11/28/80 - 12/3/80				11/28/80 - 12/3/80			
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
TSS	50	46-52	64	53-70	52	46-58	29	28-31
VSS	11	11-13	21	18-23	20	18-22	9	7-10
TS	165	160-168	199	190-208	208	20-210	130	124-138
TVS	37	34-40	52	50-54	45	44-46	22	18-28
COD	46	39-49	102	94-114	66	64-69	8.8	5.2-16
TKN	1.2	1.0-1.4	1.3	1.3-1.4	1.8	1.7-2.2	0.67	.65-.69
N-NO_3	0.6	0.5-0.7	1.3	1.3-1.4	1.8	1.6-2.6	1.2	1.1-1.3
N-NH_3	0.04	.01-.11	0.10	0.08-0.12	0.04	.01-.11	0.00	0.00-.01
Dis-Phos	0.11	.07-.11	0.06	.05-.06	0.08	.05-.09	0.06	0.06-0.07
T-Phos	0.33	.25-.38	0.27	.26-.29	0.28	.25-.33	0.15	.14-.16

b. Stormwater Runoff Simulation Model

Model Overview

This section describes a predictive tool used for the estimation of the quantity and some aspects of the quality of runoff from small watersheds with various categories of urban and non-urban land uses. The water quality parameters included are biochemical oxygen demand (BOD), chemical oxygen demand (COD), total nitrogen in terms of elemental nitrogen (N) and total phosphorus, (TP).

Runoff volumes are calculated using the rational formula. Hourly rates of runoff from the smaller segments into which the watershed is subdivided are added in order to obtain the hourly runoff from the whole watershed. The use of the Rational formula is usually limited to estimation of runoff from areas no larger than 6 square miles, a limit adhered to in this analysis.

For the Lake Quinsigamond basin the simulation program analyzes seven independent sub-basins (see Figure III-3). These model cells are analyzed one at a time. Through each cell the inputed storms are routed, determining for each storm the total and maximum hour runoff, pollutant mass loads and concentrations. The average and standard deviation of these values, computed over a larger number of storms, are then determined for each cell.

The basic equations for the predictions of runoff as well as pollutant loads accumulation and washoff are the same as those of the model "STORM". The structures of the two programs, as well as their capabilities are nevertheless entirely different, the present program being much simpler than "STORM". The objective pursued in its development was precisely that of creating a predictive mechanism for the analysis of non-point source pollution that would be simpler to use, less expensive to run and yet produce results in terms of estimated loads emission and concentrations with a degree of reliability similar to that of model "Storm". It is worth noting that the program developed for this effort can treat the areal deposition loadings during dry weather in

MODEL CELL BOUNDARIES

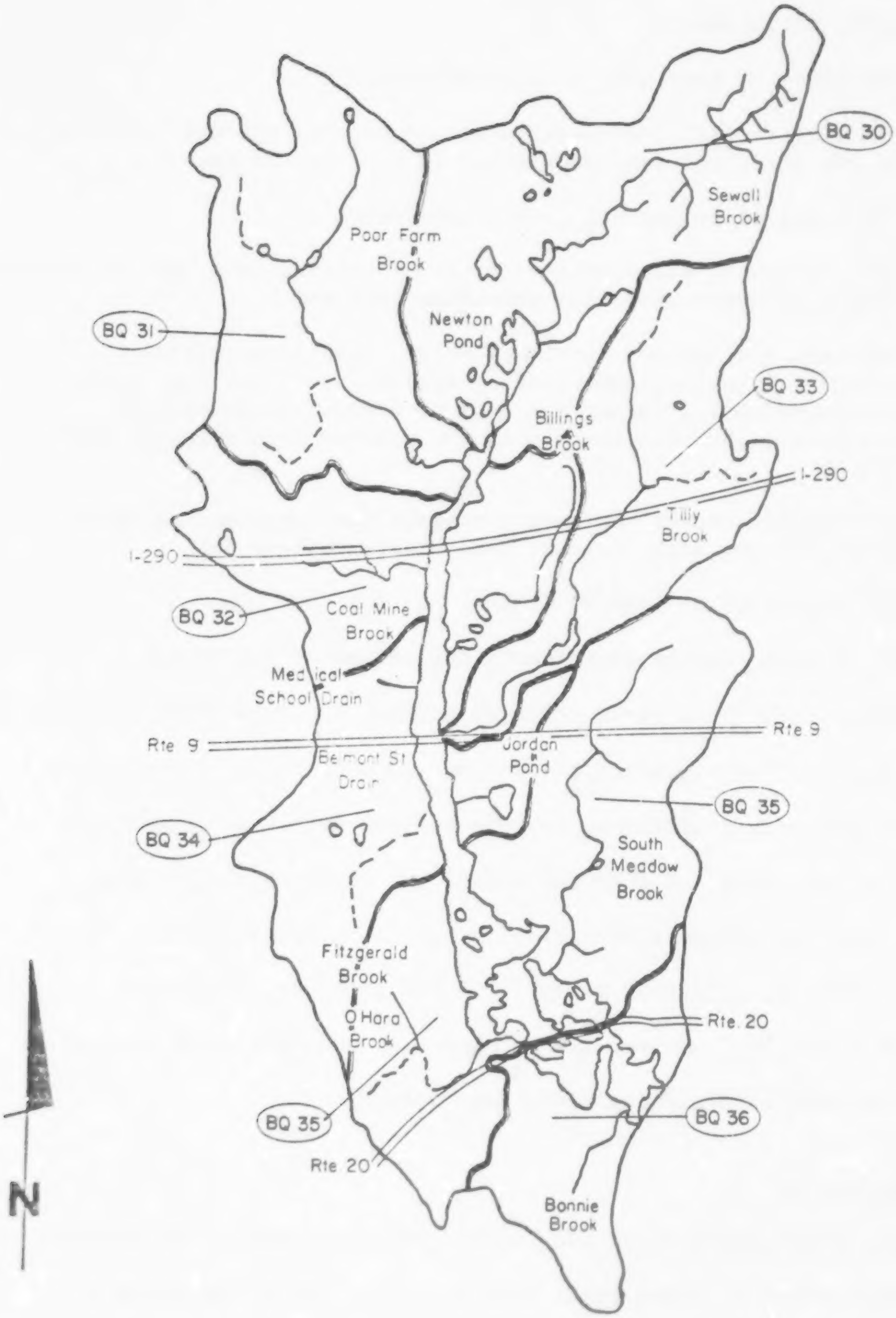

BQ 30
Sewall Brook
Poor Farm Brook
Newton Pond
BQ 31
BQ 33
Billings Brook
I-290
Tilly Brook
I-290
BQ 32
Coal Mine Brook
Medical School Drain
Rte 9
Rte 9
Jordan Pond
Belmont St Drain
BQ 35
BQ 34
South Meadow Brook
Fitzgerald Brook
O Hara Brook
Rte. 20
BQ 35
BQ 36
Rte. 20
Bonnie Brook
N

FIGURE III-3

either a deterministic mode (fixed value) like model "STORM" or in a stochastic fashion (randomly varying). Preliminary assessments for runoff to Lake Quinsigamond were determined using fixed, non-stochastic accumulation factors.

The program uses a varity of parameters to characterize the Lake Quinsigamond basin, including:

- The types of land uses to be considered;
- The area of each individual drainage segment and the fractions of the different land uses found in each one of them;
- The types of pollutants to be considered;
- Mean values of accumulation factors for urban land uses or average runoff concentrations for non-urban land use ;
- Rainfall information, storm by storm, consisting of:total rainfall duration; number of antecedent dry days; the amount of precipitation during the hour of maximum intensity and the hour within the storm when the maximum precipitation took place;
- The coefficient of depression storage for urban and non-urban land uses and daily rate of evapotranspiration; and
- The fractions of impervious area per land-use type.

For each of seven sub-basin segments the values of runoff and the loads and concentrations for a given drainage segment are determined for each storm and for each pollutant. Runoff loads and concentrations are calculated for the entire storm and,in addition, for the maximum hourly precipitation. From the various time series of computed runoff and loadings,the program determines the mean and standard deviation of runoff, pollutant loads and concentrations over the number of storms. In the same way, the series of maximum hourly runoffs, maximum hourly loads and concentrations, pollutant by pollutant, are used to determine their mean values.

Land Use Discretization

The Lake Quinsigamond basin was divided into a number of independent catchement areas. U.S.G.S. topographic maps and storm drain systems maps were used to identify catchment boundaries. For simulation work the basin was divided into seven major catchment areas. Figure III-3 shows these seven major divisions.

Present Conditions

Present land use estimates for 1975 were based on land use maps developed by the Central Massachusetts Regional Planning Commission (CMRPC), and on zoning and land use maps developed by the Worcester Office of City Planning and Community Development. Catchment divisions were superimposed on the available land use maps and common use areas outlined. Areas for each use category were totaled by counting squares on an overlaid grid system. Total catchment areas were calculated using a planimeter. Land use areas were adjusted to match the more accurate planimetered total catchment areas. Land use categories used were those specified by NURP for level three catchment descriptions.

Assumptions were necessary to interpret the different categorizations of the available land use maps into the desired NURP categorizations and simulation model categorizations. Wetlands were totaled separately from lakes for NURP purposes, but were considered the same as lakes for modeling purposes. Highways were considered commercial uses owing to the similarity with high traffic densities in commercial areas. Park lands and forested lands were separated from wetlands and open (vacant) lands with the aid of U.S.G.S. topographic maps when the land use maps were not clear as to the distinction. For the Worcester area maps, high density housing (9+ dwelling units per acre) was attributed to the maps category of multi-family housing if the housing also lay in an area zoned for high density housing. Multi-family housing in areas zoned otherwise was considered medium density housing (2-8 units per acre).

Land use estimates for present conditions were made for catchment division. Table III-9 presents the resulting estimates for the simulation model catchments.

Future Land Use Data

Future land use predictions were based on projections made by the CMRPC for towns in the Quinsigamond basin. The same proportional increases per land use category as projected by the CMRPC for towns were used to make projections for the Quinsigamond model catchment divisions. The numbers were adjusted as judged necessary by EDP when conditions within the catchment division were clearly different from average conditions for the town. The resulting projected land use areas for 1995 conditions are presented in Table III-10.

Runoff Quantity

The basic equations for the prediction of runoff quantity, as well as quality, are the same as those used in model STORM only that they are applied here for different time intervals. Runoffs and loads for both urban and non-urban areas are calculated for three different stages of a storm. The input data on each storm is:

P_{TOT} = Total depth of rainfall during the storm (in);

T = duration of the storm (hr);

N_d = number of dry days anteceding the storm (day);

P_{max} = depth of precipitation during the hour of maximum precipitation (in); and,

T_{max} = hour within the storm when maximum precipitation took place.

This information allows the separation of any storm into three segments; namely, precipitation before maximum hour, during maximum hour and after maximum hour. Figure III-4 illustrates a few possible cases that can occur. The average precipitation outside the hour of maximum rainfall is given by:

$$P_{avg} = \frac{(P_{TOT} - P_{max})}{(T - 1.0)} \quad \text{(in/hr)} \qquad (1)$$

TABLE III-9

Present Land Use Estimates (acres) for Model Cell Catchment Divisions

CD NM	TOT	LD	MD	HD	COM	IND	P/F	OPN	WTR
BQ 30	2968	77	319	0	4	126	1493	373	575
BQ 31	2303	5	653	81	46	158	944	395	21
BQ 32	1846	102	388	26	233	162	579	138	218
BQ 33	1836	183	180	0	120	30	908	101	314
BQ 34	1637	15	762	75	239	57	265	131	94
BQ 35	3230	42	1123	18	196	68	1108	277	398
BQ 36	573	0	134	0	58	22	149	37	174

LD = low density : 0-2 dwelling units per acre
MD = medium density: 2-8 dwelling units per acre
HD = high density: 9+ dwelling units per acre
COM = commercial: includes highways, parking lots
IND = industrial: includes quarries
P/F = park/forest: forested land or public parks
OPN = open: unforested, undeveloped land
WTR = water: includes lakes and wetlands
TOT = total

TABLE III-10

Future Land Use Estimates (acres) for Model Cell Catchment Divisions

		Residential							
	TOT	LD	MD	HD	COM	IND	P/F	OPEN	WATER
BQ 30	2968	106	440	5	9	351	1190	290	575
BQ 31	2303	6	712	100	81	270	780	333	21
BQ 32	1846	103	392	44	289	188	522	90	218
BQ 33	1836	253	268	8	127	60	736	70	314
BQ 34	1637	15	770	98	256	58	283	63	94
BQ 35	3230	44	1179	24	219	71	1069	226	398
BQ 36	573	0	142	0	63	24	142	28	174

TOT: total
LD : low density residential: 0-2 dwelling units per acre
MD : medium density residential: 2-8 dwelling units per acre
HD : high density residential: 9+ dwelling units per acre
COM: commercial: includes highways, parking
IND: industrial: includes quarries
P/F: forested or park land
OPEN: unforested, undeveloped land
WATER: includes lakes and wetlands

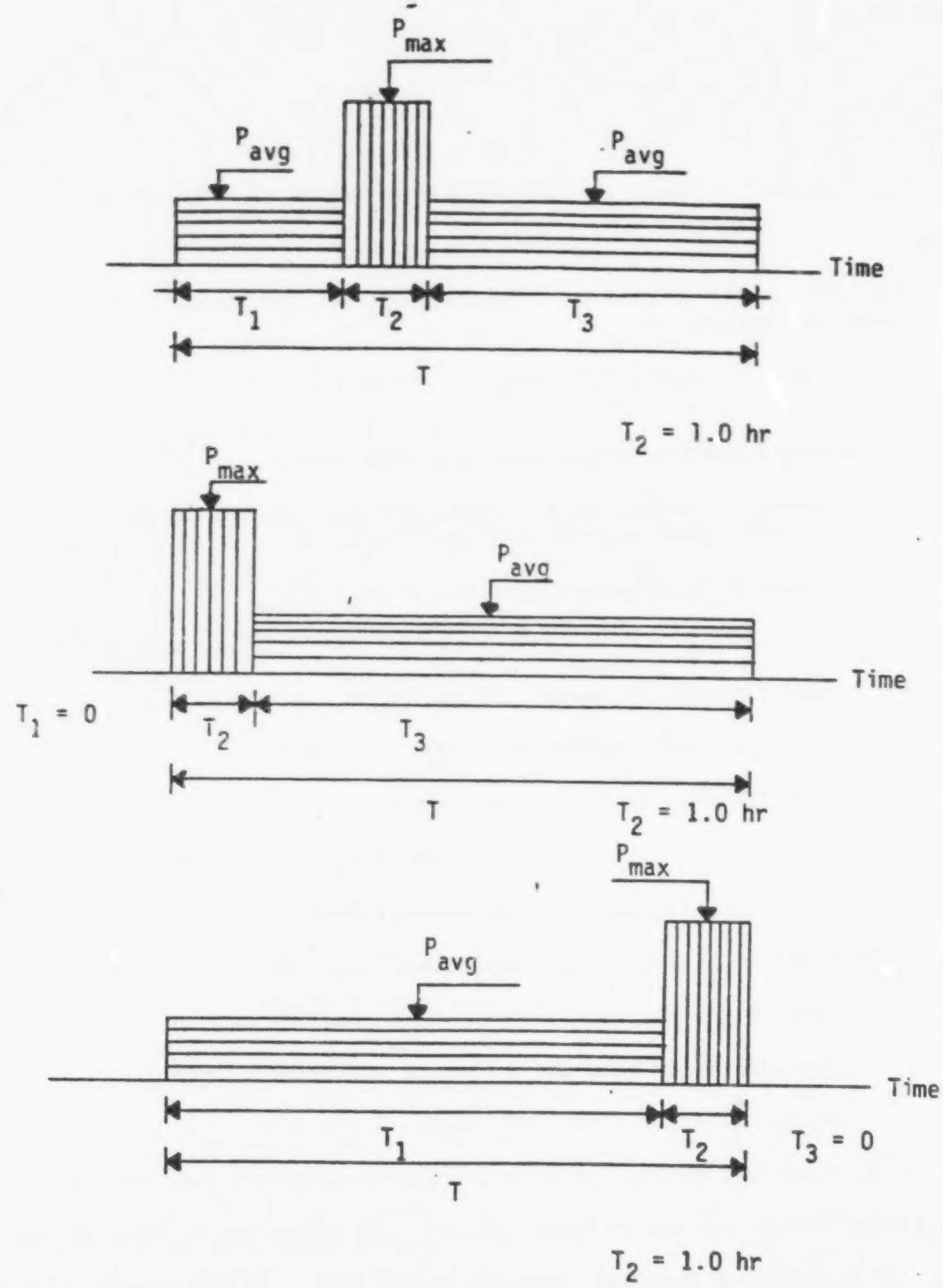

P_{max}
P_{avg}
P_{avg}
Time
T_1
T_2
T_3
T
T_2 = 1.0 hr
P_{max}
P_{avg}
Time
T_1 = 0
T_2
T_3
T
T_2 = 1.0 hr
P_{max}
P_{avg}
Time
T_1
T_2
T_3 = 0
T
T_2 = 1.0 hr

FIGURE III-4 THREE POSSIBLE RAINFALL PATTERNS

The time duration T_i indicated in Figure III-4 are given by:

$$T_1 = T_{max} - 1.0 \qquad (2)$$

$$T_2 = 1.0$$

$$T_3 = T - T_{max}$$

For each one of the three phases defined above, the following equations apply:

The urban runoff over a political segment for any phase 1 of the storm is computed by:

$$R_{ui} = C_u(P_i * T_i - D_{ui}) \qquad (i=1.3) \qquad (3)$$

where:

R_{ui} =urban runoff in inches over the urban area;

C_u = composite urban runoff coefficient that depends on the urban land uses in political segments;

P_i = rainfall in inches/hr over the area. $P_i = P_{max}$ at the hour of maximum precipitation and $P_i = P_{avg}$ otherwise:

T_i = time duration of phase i of the storm, (hours); and,

D_{ui}= available urban depression storage (inches).

The composite runoff coefficient in turn is given by:

$$C_u = C_p + (C_{imp} - C_p) \qquad j=1\ X_j F_j \qquad (4)$$

where:

C_p = runoff coefficient for pervious surface;

C_{imp}= runoff coefficient for impervious surfaces;

X_j = area of the political segment with land use j;

F_j = fraction(%) of land use j that is impervious; and,

L = total number of urban land uses.

Rains occurring during the early part of a storm are retained in the vegetative cover and in surface puddles, ditches, and other depressions in the soil surface. This volume of retained rainfall is designated by the general term, "depression storage".* The amount of depression storage available at any point in time is a function of past rainfall and evaporation rates. This function is computed continuously by the following expression:

---

*Slight levels of rainfall had already been deleted from rainfall records used here. The nominal depression storage coefficients were reduced to reflect this adjustment.

$$D_{ui} = D_{ou} + N_d * K\ i = 1D_{ui} - D_{umax} \qquad (5)$$

where: D_{ou} = available urban depression storage at the end of previous rainfall (inches);

N_d = number of dry days since previous rainfall;

K = recession factor representing the recovery (evaporation) of depression storage (inches/day); and,

D_{umax} = maximum available urban depression storage (inches).

Depression storage is also updated for each phase of the storm (i = 1-3).

Runoff from non-urban areas is computed by using the same equation defined for the urban runoff except for non-urban areas the fractions F_j in equation 4 are all equal to zero resulting in :

$$C_n = C_p$$

where C_p is an input value. For the non-urban runoff, equations 3 through 5 become:

$$R_{ni} = C_n\ (P_i * T_i - D_{ni}) \quad (i = 1,3) \qquad (6)$$

$$C_n = C_p \qquad (7)$$

$$D_{ni} = D_{on} + N_d * KD_n - D_{nmax} \quad i = 1 \qquad (8)$$

In equation 6 through 8, the variables have the same meaning indicated previously with "n" now standing for "non-urban" in place of the "u". Again, depression storage is updated for each phase of a storm.

Runoff Quality

As in model"STORM"the deposition of the different pollutants in urban areas is correlated with the deposition of dust and dirt over the area. The runoff quality is defined by BOD, COD, total nitrogen and total phosphorus and is calculated for the three phases of the storm as follows:

A. Urban Pollutant Accumulation between storms, PPU_j

$$PPU_1 = \underset{j=1}{\overset{LU}{(}} PU_{j,1} + N_d * D_{j,1} * A_j \qquad (9)$$

where:

PPU_1 = totals pounds of pollutant 1 on urban land use at the beginning of the storm;

$PU_{j,1}$ = total pounds of pollutant 1 remaining on urban land use j at the end of last storm;

N_D = number of dry days since last storm;

$D_{j,1}$ = deposition coefficient of pollutant 1 on land use type j, in pounds per unit area per day;

A_j = area of land use type j;

LU = total number of urban land uses.

No effects of street sweeping is accounted for in the program.

B. Urban Pollutant Washoff: computed at each phase i by:

$$WU_{1i} = PPU_1 * (1-e^{-E_u * R_{ui}}) \quad (i=1,3) \qquad (10)$$

where:

WU_{1i} = washoff of pollutant 1 in pounds over the time period T_i;

E_U = urban washoff decay coefficient; and,

T_i = time duration of phase i of the storm.

Notice from equation 3 that R_{ui} includes all runoff for period T_i.

At the end of each phase of the storm, the remaining loads of pollutant 1 on soil are updated by :

$$PPU_{1,i} = PPU_{1,i-1} - WU_{1,i} \qquad (I=1,3) \qquad (11)$$

When i=1, $PPU_{1,o}$ on the right hand side of equation 11 is given by equation 9.

For non-urban areas including park lands the concept of pollutant accumulations is considered inappropriate. Instead average pollutant concentrations are assumed for runoff waters.

Accumulation factors for urban land uses and average runoff concentration for non-urban land uses are presented in the following section on model calibration.

Calibration of the Runoff Model

Flow Calibration

Storm runoff volumes are calculated using runoff coefficients and the Rational formula. Each urban land use is assigned a percent imperviousness. A runoff coefficient is associated with urban imperviousness, urban non-impervious, and non-urban areas. All of these parameters were adjusted to calibrate the model. The field calculated percent imperviousness were used as guidelines to maintain a reasonableness in adjusting the parameters. The resulting parameters are as follows:

Runoff Coefficient	
Urban impervious surfaces	0.90
Urban non-impervious surfaces	0.15
Non-urban land uses	0.15

Percent Imperviousness	
Low density residential	0.10
Medium density residential	0.15
High density residential	0.25
Industrial	0.30
Commercial	0.50

The runoff model calculates the numeric average of the total event runoff volume for all events. This statistic was used to define calibration. (In essence this calibration strategy is the same as matching total runoff volume for all events modeled.) For the calibration run a complete set of 13 measured flow events was compared to the modeled run of the same 13 events.

Water Quality Calibration

Water quality was calibrated by using the analagous statistic for the numeric average of average storm concentration of all events. In calculating the average storm concentration for comparison, a flow-weighted average was taken. In calculating the numeric average of a number of events no weighting was done. Average storm concentration was selected for calibration over average loadings as the variance in average storm concentration was much less. In using an unweighted numeric average over all events it was assumed that the variance in concentration was independent of storm flows. This is not entirely true but reasonable for the rough calibration procedure.

For the water quality run a set of 13 sampled events was modeled. As a complete set of 13 events was not available at any water quality sampling station, an incomplete set of measured events was used to compare to the statistics of the 13 modeled events. In doing this it was assumed that the set of measured events at any given station was representative of the 13 modeled events and would produce similar average concentrations. Each station's set was examined with this assumption in mind and determined to be a reasonable representation of the larger modeled set.

Water quality was calibrated by adjusting the pollutant accumulation factors for urban areas and the average concentrations for non-urban areas. Tilly Brook was calibrated initially as it is composed predominately of non-urban land uses. The Convent was calibrated next as it is predominantly commercial. Assuming that this procedure will identify non-urban and commercial loadings, these land uses were fixed for further calibration. The residential and industrial loadings were then adjusted until the other four sampling stations were calibrated. The resulting adjusted accumulation and average concentration factors are as follows:

Urban Accumulation Factors (pounds per acre per day)	TSS	Total Nitrogen	Dissolved Phos.	Total Phos.
Low Density Residential	0.2	0.01	0.002	0.005
Medium Density Residential	4.0	0.09	0.004	0.02
High Density Residential	8.0	0.13	0.005	0.04
Commercial Density Residential	6.0	0.08	0.004	0.02
Industrial Density Residential	9.0	0.14	0.004	0.06
Non-Urban Average Concentrations (mg/l)				
Forest/Park	2.0	0.27	0.02	0.04
Open	2.0	0.27	0.03	0.04

The following tables(III-11 through III-15) present the comparison between measured and modeled parameters. Five parameters were modeled: flow, average

TABLE III-11

Calibration Comparison

VARIABLE: Flow (1000 ft^3)

Date	Rain	P1 Jordan Pond		P2 Rt.9		P3 Locust		P4 Anna		P5 Convent		P6 Tilly	
		meas	mod	meas	mod	meas	mod	meas	mod	meas	mod	meas	mod
6/16	.2	-	18	-	57	-	22	241	73	-	20	-	136
6/20	.24	23	23	24	73	12	28	87	94	38	26	-	180
6/29	2.18	167	259	650	842	430	316	563	1107	221	304	-	2294
7/8	.41	53	43	76	140	60	53	106	182	33	50	-	365
7/17	.38	39	40	102	129	93	48	130	167	28	46	-	332
7/29	1.82	145	215	362	699	405	265	1030	919	250	253	-	1902
8/2	.06	5	1	19	3	9	1	154	4	11	1	-	5
8/3	.22	15	24	57	78	31	29	113	101	49	28	-	197
8/11	.05	6	4	8	12	2	4	87	16	20	4	-	34
9/9	.12	4	8	7	26	6	10	5	31	-	9	-	49
9/18	*1.04	33	120	246[2]	390	162	147	202	511	-	141	-	1052
9/26	.35	17	36	11	117	38	44	558	151	-	42	-	300
11/28	1.59	-	187	509	608	276	228	-	799	-	220	-	1651
Mean		48	75	173	240	84	90	235	310	82	86	-	650

*Rain 9/18 1.04 at Worcester (modeled) .72 at Quinsigamond (measured)

2 low, portion of meas. event off scale

TABLE III-12

Calibration Comparison

VARIABLE: Total Suspended Solids (mg/l) storm average

		P1 Jordan Pond		P2 Rt.9		P3 Locust		P4 Anna		P5 Convent		P6 Tilly	
DATE	Rain	meas	mod	meas	mod	meas	mod	meas	mod	meas	mod	meas	mod
6/16	.2		220		280		243	170	214		275		112
6/20	.24		174		211		195		170	19	185		84
6/29	2.18	32	48		48		59	47	49	21	29		20
7/8	.41	57	163		196		183		156	79	178		74
7/17	.38	122	100	600	111	730	118	320	100	122	81		45
7/29	1.82	8	29	118	26		37		31	42	13		12
8/2	.06	26	231	80	311	69	256	58	258	17	319		192
8/3	.22	42	225	231	278		249	106	215	56	262		106
8/11	.05	8	220	18	262	47	246	12	205	4	233		93
9/9	.12	39	206	110	256	78	235	14	222		225	33	133
9/18	1.04	324	238	790	264	440	276	500	231		201	249	101
9/26	.35		89		83	53	115	19	97		39		39
11/28	1.59		128		133		155		129		93	6	54
Mean		73	159	280	189	237	182	138	160	45	164	96	82
Standard Deviation		100	73	296	98	287	79	168	73	40	102	133	50

TABLE III-13

Calibration Comparison

VARIABLE: Total Nitrogen (TKN + NO_3) (mg/l) storm average

		P1 Jordan Pond		P2 Rt.9		P3 Locust		P4 Anna		P5 Convent		P6 Tilly	
Date	Rain	meas	mod	meas	mod	meas	mod	meas	mod	meas	mod	meas	mod
6/16	.2		4.4		4.9		5.1	2.8	4.5		3.9		2.2
6/20	.24		3.5		3.7		4.1		3.6		2.6		1.7
6/29	2.18	3.1	1.0		0.9		1.3	3.2	1.1	2.3	0.4		0.5
7/8	.41	1.7	3.3		3.4		3.9		3.3	1.0	2.5		1.5
7/17	.38	3.4	2.0		2.0		2.5	3.9	2.2	2.3	1.2		0.9
7/29	1.82	1.0	0.6		0.5		0.8		0.7	1.9	0.2		0.4
8/2	.06	3.2	4.6	3.4	5.4	4.1	5.4	2.5	5.4	3.1	4.5		3.5
8/3	.22	1.6	4.5	3.5	4.9	-	5.3		4.6	0.9	3.7		2.0
8/11	.05	2.9	4.4	3.0	4.6	3.1	5.2	2.4	4.3	1.9	3.3		1.8
9/9	.12	3.8	4.1	6.9	4.5	6.5	5.0	3.6	4.7		3.2	5.3	2.5
9/18	1.04	2.2	4.7	3.6	4.6	4.3	5.9	3.2	4.9		2.9	2.3	2.0
9/26	.35		1.8		1.5	3.6	2.5	2.9	2.1		0.6		0.8
11/28	1.59		2.6		2.3		3.3		2.8		1.3	0.4	1.1
Mean		4.1	3.2	4.3	3.3	3.1	3.9	1.9	3.4	1. 9	2.3	1.7*	1.6
Standard Deviation		1.6	1.5	1.3	1.7	0.5	1.6	0.8	1.5		1.4	2.2	0.9

*- includes two events (12/3 and 12/10) not modeled

TABLE III-14

Calibration Comparison

VARIABLE: Dissolved Phosphorous (mg/1) storm averages

		P1 Jordan Pond		P2 Rt.9		P3 Locust		P4 Anna		P5 Convent		P6 Tilly	
Date	Rain	meas	mod	meas	mod	meas	mod	meas	mod	meas	mod	meas	mod
6/16	.2		.22		.22		.24		.22		.20		.13
6/20	.24		.18		.17		.20		.18		.13		.10
6/29	2.18		.05		.04		.06		.05		.02		.03
7/8	.41	.08	.17		.16		.18		.16	.03	.13		.09
7/17	.38	.46	.10	.14	.09	.16	.12	.18	.11	.06	.06		.06
7/29	1.82	.42	.03		.02		.04		.04	.56	.01		.03
8/2	.06	.05	.23	.15	.25	.12	.26	.07	.26	.03	.22		.20
8/3	.22	.13	.23	.09	.22	-	.25		.22	.02	.19		.12
8/11	.15	.04	.22	.03	.21	.09	.25	.05	.21	.02	.17		.11
9/9	.12	.06	.21	.16	120	.22	.24	.17	.23		.16	.45	.14
9/18	1.04	.15	.24	.25	.21	.22	.28	.24	.24		.14	.19	.12
9/26	.35		.09		.07	.27	.12	.16	.10		.03		.05
11/28	1.59		.13	.	.11		.16		.14		.07	.02	.07
Mean		.17	.16	.14	.15	.18	.18	.15	.17	.12	.12	.14*	.10
Standard Deviation		.17	.07	.07	.07	.07	.08	.07	.07	.22	.07	.19*	.05

*includes two events (12/3 and 12/10) not modeled

TABLE III-15
Calibration Comparison

VARIABLE: Total Phosphorous

		P1 Jordan Pond		P2 Rt.9		P3 Locust		P4 Anna		P5 Convent		P6 Tilly	
Date	Rain	meas	mod	meas	mod	meas	mod	meas	mod	meas	mod	meas	mod
6/16	.2		1.1		1.36		1.27	.56	1.07		.96		.57
6/20	.24		.85		1.02		1.02	-	.85	.07	.65		.44
6/29	2.18	.2	.23		.24		.31	.66	.25	.13	.11		.12
7/8	.41	.23	.79		.95		.96		.79	.25	.62		.39
7/17	.38	1.58	.49	1.28	.54	1.60	.62	1.61	.51	1.41	.28		.24
7/29	1.82	.56	.14		.13		.20		.16	1.16	.05		.08
8/2	.06	.15	1.12	.57	1.50	.48	1.35	.2	1.29	.11	1.11		.96
8/3	.22	.28	1.1	.50	1.34	-	1.31		1.08	.20	.91		.54
8/11	.05	.06	1.1	.26	1.27	.38	1.29	.1	1.03	.04	.81		.48
9/9	.12	.15	1.0	1.68	1.24	1.1	1.23	.31	1.11		.78	.78	.67
9/18	1.04	.48	1.2	1.59	1.28	2.3	1.45	.86	1.16		.70	.75	.52
9/26	.35		.43		.40	1.1	.61	.46	.49		.14	.03	.21
11/28	1.59		.62		.64		.82		.65		.33		.28
Mean		.41	.78	.98	.92	1.2	.96	.59	.80	.42	.57	.32*	.42
Standard Deviation		.47	.36	.61	.47	.8	.41	.47	.36	.54	.35	.40*	.24

*Includes two events (12/3 and 12/10) not modeled storm concentrations for total suspended solids, total nitrogen, dissolved phosphorus, and total phosphorus. Total nitrogen was the total of TKN and N-NO_3 (NO_2 was not measured). The parameters are compared per storm and the numeric average and standard deviation of the 13 storms (modeled) or available storms (measured). The model was calibrated by matching the averages for the set.

Calibration was tested by running the model for the year 1980 and comparing the results with the expected values based on the intensive lake study done during that year. The calibration was determined to be reasonable through this procedure.

Calibration Discussion

The objective of the runoff model is to predict an annual pollution loading. The model was anchored by the six month sampling period data which indicated how the system behaves on a storm by storm basis. However, the modeling of individual storms was not attempted or considered appropriate by the model used. The variance between measured and modeled storms was not considered a problem so long as the aggregate statistics were reasonably matched. The results of the model are considered to have achieved the objective of a reasonable annual loading estimate.

The runoff model is driven by rain recorded at the Worcester airport NOAA station. For most of the 13 calibration period events the NOAA station rain totals were within a few hundreths of an inch of the locally recorded rain. However, for a few events there was a significant variance. For example, on 9/18/80 Worcester recorded 1.04 inches while the local gage recorded 0.72 inches. For the most part a strong regional difference was not observed.

The runoff model makes use of the model STORM concept of pollution accumulation. In so doing the carry-over of unwashed off materials after an event is important. For a period as short as 13 events the carry-over may have introduced error. For one, a start up problem existed which is insignificant for runs with sixty to eighty rain events, but is significant for a short number of events. The problem was solved by assuming a three day period of pollution accumulation before the 13 event period was run. Another problem is the contiguity of events. The 13 measured events were not perfectly contiguous due to small events too small to trigger the samplers. The calibration was run as if the 13 events were contiguous with dry days representing the time since the last runoff event (not the previous event in the 13 rain events set). The error created in this procedure was considered small.

In running the model for an entire year of rainfall records the different effects of seasons on runoff loadings were ignored. In reality, loadings will change seasonally. For example the decrease in phosphorus loadings observed at Tilly Brook were expected as cold weather reduced the rate of material decay. The effects of snow and spring runoff were similarly ignored.

The sampling program suggested differences between the Shrewsbury and the Worcester side of the lake. As the model considers a given land use category invariant in its loadings, this difference caused much of the inability to exactly calibrate the model. Loadings are considered higher on the Worcester side in similar land use categories. The topography is also different. Slope is greater on the Worcester side encouraging more pollutant washoff. Industrial areas on the Worcester side are generally factories or shops. In the Shrewsbury side and northern section of the lake industries are generally gravel pits. Accumulation factors were chosen in the middle range between the higher Worcester loadings and the lower east side loadings. In so doing a reasonable average for the entire basin was believed to be achieved.

Full Year Simulations

Full year simulations were run for the years 1964 through 1973 and 1979 through 1980. The simulations were driven by NOAA rain records recorded at the Worcester station. Snowfall and spring melt were ignored as discussed in the previous section. Table III-16 presents the total annual loads for the years modeled. Table III-17 presents the future conditions. Future conditions represent the future land use projections modeled with the same rain periods as used in the present conditions run.

The following presents the number of storms per year analyzed:

Year	64	65	66	67	68	69	70	71	72	73	79	80
No. of Storms	39	75	73	98	85	74	83	73	101	90	107	89

Conclusions on the utility of the sampling program

The Lake Quinsigamond watershed has been studied in the past with limited data and theoretical loading estimates. At the close of an extensive field monitoring program it is appropriate to consider the extent to which our knowledge of storm runoff parameters has been improved.

Historically, data concerning Quinsigamond storm runoff is extremely limited. There was a 1971 survev that produced a handfull of storm flow grab samples. Other than these data, sampling has been confined to lake samples and dry weather tributary samples.

A large study was conducted for the Central Massachusetts Regional Planning Commission (CMRPC) which included the Quinsigamond watershed. The study utilized a range of pollution accumulation factors taken from literature sources and model STORM's mechanics to generate loadings to the lake. It was this modeling methodology that became the basis of the model utilized in this study.

The preliminary model runs in the present study took a number of departures from the original CMRPC work. The alterations were made primarily to produce a model that was believed to be more appropriate to Lake Quinsigamond. These changes included a major change in the area of segment BQ 36, the inclusion of a 3 day accumulation limit, and altered accumulation factors.

TABLE III-16

Annual Loadings for Present Land Uses

Year	Discharge acre-inches x 1000	Annual Loads (pounds x 1000)			
		TSS	Tot.Nitro.	Dis.Phos.	Tot.Phos.
1964	45	660	14	0.7	3.5
1965	77	1380	27	1.4	7.3
1966	104	1680	34	1.7	8.8
1967	135	2060	42	2.1	10.7
1968	121	1700	35	1.7	9.0
1969	119	1400	29	1.5	7.5
1970	102	1780	35	1.8	9.3
1971	114	1400	29	1.5	7.4
1972	190	2590	53	2.7	13.7
1973	151	1500	32	1.7	8.1
1979	155	2400	49	2.5	12.8
1980	99	1930	38	1.9	10.1

TABLE III-17

Annual Loads for Future Land Uses

Year	Discharge acre-inches x 1000	Annual Loads (pounds x 1000)			
		TSS	Tot.Nitro	Dis.Phos	Tot.Phos.
1964	49	828	16	0.7	4.4
1965	83	1700	33	1.6	9.0
1966	112	2060	40	1.9	11.0
1967	139	2400	47	2.3	13.0
1968	130	2100	40	1.9	11.0
1969	127	1760	34	1.6	8.7
1970	110	2200	42	2.0	11.6
1971	122	1700	33	1.6	9.2
1972	204	3200	61	3.0	17.0
1973	162	1860	37	1.8	10.1
1979	167	2990	58	2.8	15.9
1980	106	2370	45	2.2	12.6

After the sampling program, the model could be adjusted to match the extensive data collected in the watershed. The following discussion presents the changes in final loadings as a result of the additional data collected concerning the watershed.

Flow and Mass Loadings

Tables III-18 through III-20 summarize the development of loading data by examining flow, total nitrogen, and total phosphorus. respectively.

The 1971 survey figures are single concentration numbers or a range if more than one grab sample was taken. The flow volume estimate in the 1971 survey was made by subtracting known dry weather Lake input rates from wet weather Lake output rates to arrive at storm loads. The CMRPC model run includes some land in segment BQ 36 which was determined to drain into neither Lake Quinsigamond nor Flint Pond. Model runs are for both 1968 and 1971 (1968 is a slightly "dryer" year,but comparable). The 1971 survey was made between April and August (27 rain events).

The 1971 survey data represented single grab samples and back-calculated flows which were highly uncertain as average concentration and flow estimators. As the present sampling program demonstrated, concentrations will vary over the course of a rain event. "First-flush" phenomenon were observed, and concentrations varying with rain intensity were observed. It is not surprising therefore that the figures calculated or measured in latter studies varied significantly from the 1971 survey data points.

The CMRPC model predicted very different loadings with flows over four times those estimated in the 1971 study, and concentrations of total phosphorus as much as four times those measured in 1971. Adjustments to better match Quinsigamond in the preliminary modeling work for this study resulted in lower loadings. However, the loadings in the preliminary model are still significantly higher than the 1971 survey. Storm flows are about three times

TABLE III-18
Information Development: Flow

	1971 Survey	CMRPC for 1968	Preliminary model run (1968)	Calibrated model run (1968)	Calibrated model (1971)
BQ 30 Newton Pond (lake inlet)	-	485	360	212	223
BQ 31 Poor Farm Brook	-	456	407	242	255
BQ 32 Coal Mine Brook	-	450	347	215	226
BQ 33 Tilly Brook	-	321	256	156	165
BQ 34 Fitzgerald Brk. and Jordan Pond	-	264	352	222	234
BQ 35 O'Hara Brook & S.Meadow Brk.	-	706	534	326	344
BQ 36 Bonnie Brook	-	328	82	106	112
Lake Total ave. per storm	830*	3010	2300	1479	1560

* Estimate based on water quality balance between April 14 and August 17 - 27 storm events.

TABLE III-19

Information Development: Total Nitrogen

	1971 Survey	1968 CMRPC		1968 Preliminary model run		1968 Calibrated model run	
	mg/l average	*PPS	mg/l	*PPS	mg/l	*PPS	mg/l
BQ 30 Newton Pond (Lake inlet)	-	148	1.9	98	1.5	43	1.3
BQ 31 Poor Farm Brook	-	146	2.0	128	1.8	75	1.9
BQ 32 Coal Mine Brook	-	149	1.9	99	1.7	62	1.7
BQ 33 Tilly Brook	-	97	1.2	56	1.3	27	1.1
BQ 34 Fitzgerald Brk. & Jordan Pond	-	86	1.9	106	1.8	79	2.1
BQ 35 O'Hara Brook &S. Meadow Brk.	-	204	1.5	151	1.7	100	1.8
BQ 36 Bonnie Brook	-	101	1.9	23	1.8	34	1.9
Lake Total		930		660		420	

*Pounds Per Storm

TABLE III-20

Information Development: Total Phosphorous

	1971 Survey mg/l average	1968 CMRPC *PPS	1968 CMRPC mg/l	1968 Prelim. model run *PPS	1968 Prelim. model run mg/l	1968 Calib. model run *PPS	1968 Calib. model run mg/l	calibrated model (1968)
BQ 30 Newton Pond (Lake inlet)	-	59	0.54	50	0.62	12	0.36	.38
BQ 31 Poor Farm Brook	0.15	40	0.55	45	0.55	20	0.51	.54
BQ 32 Coal Mine Brk.	0.11	42	0.46	32	0.49	18	0.50	.53
BQ 33 Tilly Brook	0.17	32	0.67	30	0.53	7	0.28	.29
BQ 34 Fitzgerald brk. & Jordan Pond & Rt.9 drain	0.14 0.44	15	0.27	28	0.45	20	0.51	.54
BQ 35 O'Hara Brook & S.Meadow Brk.	0.12	69	0.52	54	0.51	24	0.43	.46
BQ 36 Bonnie Brook	-	40**	0.58	8**	0.51	10	0.55	.59
Lake Total (average per event)	-	297		247		110		

* Pounds per storm

** BQ 36 area was substantially changed between the CMRPC run and subsequent runs.

as high and concentrations are four times as high (about equivalent to the CMRPC model).

The final calibrated model suggests loadings about midway between the 1971 survey and the CMRPC model estimates. Without the present measuring program, errors on the order of 50% would have occurred in loading estimates. The 1971 survey would have suggested loadings too low which would be expected from grab samples that are likely to have missed the short flow periods when loads were relatively heavy. The theoretical modeling efforts would have overestimated loadings by over 60% possibly missing the effects of the numerous ponds in the area that may be acting as pollution buffers.

Uncertainty

Irregardless of the resulting variations in loading estimates, the NURP data gathering process does much to decrease the uncertainty attributed to the estimates. Although uncertainty will always remain, it is clear that the activities to date have greatly reduced uncertainty. The degree of confidence attributable to the loading estimates is important in terms of the stakes involved. Error in the estimates can mean overdesign of abatement options and resulting excessive costs, or underdesign of abatement options and resulting environmental damage. Even if additional investment in developing understanding does not produce significantly different conclusions, the exercise may be well worth the cost by increasing the certainty in the estimate.

The 1971 survey produced highly uncertain numbers. Data were very limited, amounting to one or a few grab samples at any location for each storm. This procedure may miss high concentrations in the first flush and generally is a poor estimate of the average storm concentration. Total volumes were calculated by subtracting uncertain estimates of ground water flow, tributary flow and evaporation from lake output, and are also highly uncertain.

The model runs from both the CMRPC study and the preliminary run for this study are more comprehensive. These runs cover the entire watershed over long periods of rainfall. However, as the loading parameters were derived from literature sources, the procedure lacks a strong relationship to the area in question.

The sampling program produced very accurate storm data for a number of storm events. Flows were accurately determined. Average concentrations were accurately flow-weighted. By calibrating the model to the data collected, a great deal of site-specific information has been added to the process. Although there is still some uncertainty in expanding the sampling period and sampling areas to the entire watershed and longer time periods, one can still speak confidently of storm flow contributions and expected pollution concentrations.

Overall Distribution of Loads

The monitoring program gives the most accurate information as to how the pollutant loads are distributed over the Lake Quinsigamond watershed. The runoff simulation model was designed to utilize this monitoring program to estimate annual loads for the entire watershed. Although the model is believed to have properly estimated these total loads, the model did not estimate the distribution of loads over the watershed. This result is primarily because the differences in topography and flow dynamics were not simulated in the model. In spite of the orientation toward total watershed loads, the model does provide approximate estimates of the distribution of loads by major catchment. Table III-21 presents the percentages of flow volume and pollution loads attributable to major catchments by the simulation model.

Table III-21 also demonstrates the importance of the less urbanized catchments such as Poor Farm Brook, Tilly Brook, Newton Pond Outlet, and South Meadow Brook. To a large degree these areas are composed of wetlands and forested areas. However, even though the loadings per acre for these watersheds are lower than in the more urbanized areas, the loading contribution to the lake is

Table III-21

Distribution of Storm Loads
(percentage of total loading)

Drainage Area	Flow	TSS	Total Nitrogen	Dissolved Phos.	Total Phos.
Belmont St. Drain (Rt. 9)	6	12	11	7	8
Fitzgerald Brook (Anna St.)	8	8	6	9	9
Jordan Pond Outlet	1	1	3	2	1
Tilly Brook	11	6	6	8	6
Newton Pond Outlet	14	9	9	11	11
Poor Farm Brook	17	17	18	17	19
Coal Mine & Billings Brook	15	17	15	14	16
S. Meadow Brook O'Hara Brk. & Bridle Path Drain	21	21	24	25	21
Bonnie Brook	7	9	8	7	9

significant. Pollution control strategies that concentrate on the urban portion of the watershed can only deal with a portion of the wet weather pollution loading problem.

C. Receiving Water Impacts of Stormwater Sources

Estimates of average total loads to the lake indicate that wet weather flows provide the greatest amount of total suspended solids (TSS) and total phosphorus (TP). Non-storm contributions (base flows and dissolved phosphorus) play a much larger role in the case of dissolved phosphorus, (DP) and total nitrogen (TN). The following Table III-22 summarizes these estimates:

TABLE III-22

AVERAGE ANNUAL POLLUTION LOADS

parameter	atmosphere	base flow	storm flow	units
TSS	-	43	781	metric tons/yr
TN	2940	20500	16000	kg/yr
TP	88	750	4120	kg/yr
DP	88	460	810	kg/yr

Understanding the sources and quality of the stormwater contamination is essential in establishing control alternatives. The following sections examine the sources of pollutants in stormwater runoff identified as key parameters to lake quality: suspended solids, nutrients, heavy metals and bacterial/viral pollutants.

Sediments/Suspended Solids

Sediment pollution causes negative impacts through both direct and indirect means. In a direct fashion, the formation of unsightly appearances along the lake. The Route 9 area is an example of this problem. In addition, deposition in the storm conduits can cause decreased hydraulic capacity and blockages. Transparency is also decreased by sediments carried by stormwater particularly during the periods following significant rain events. Indirect impacts depend on the degree to which other pollutant sources can be attributed to particulates. In general, particulates will act as transporters of other pollutants such as heavy metals and nutrients.

Over 95% of the total suspended solids loading (in essence the non-dissolved solids fraction) comes to Lake Quinsigamond via storm runoff (see Table III-22). Only a small fraction of the solids loading is carried to the lake during dry weather flow conditions. A major reason for this is that the storm flows are better able to scour solids from the ground or deposits within the drainage system.

The areas in the Quinsigamond watershed that generate storm flows with greatest scour potential are also the areas with the heaviest solids loadings. The Worcester side of the lake (directly west) has significantly greater slopes than are found on the Shrewsbury side or in the northern or southern areas. As a result, storm runoff on the Worcester side is more rapid with greater scour potential than elsewhere in the watershed. Solids are more easily scoured, suspended in the runoff, and delivered to the lake.

Review of the stormwater monitoring data clearly shows the impact of differing topography on both the runoff hydrographs and the pollution content. Three areas were continously monitored in Worcester where slopes are relatively high: Belmont Street drain (Route 9 - P2), Fitzgerald Brook (Anna Street - P4) and Locust Street (P3, tributary to Belmont Street drain). Tilly Brook (P6) and Jordan Pond Inlet (P1) were monitoring sites representative of Shrewsbury and its lower slopes. The Convent (P5,parking lot drainage to Coal Mine Brook), although on the Worcester side, has relatively lower slopes. Poor Farm Brook (S9,flow gaged only) drains lower sloped lands similar to Tilly Brook.

The hydrographs of the monitored sites in the high sloped areas show runoff to rise quickly after the start of rain, fluctuate with high and low flows and then fall off quickly at the end of a storm. On the other hand, Tilly Brook and Poor Farm Brook rise much more slowly, with intense fluctuations buffered and hydrograph tails long and slow to drop. Jordan Pond and the Convent hydrograph characteristics lie between the above two examples as they drain much smaller areas at low slopes but without the buffering capacity of wetlands and upstream ponds.

Suspended solids concentrations are highest at the stations on the Worcester side that have high slopes. Table III-23 demonstrates this comparison which presents the percentages attributable to each station (excluding Poor Farm Brook) of flow and pollutant loadings monitored in the sampling program. (100% is the total load monitored, not the total load to the lake). As can be seen in Table III-23, the flow volume contribution is highest at Tilly Brook which drains a very large area, (Route 9 and Anna Street are next), and the other stations represent smaller relative flow contributions. The suspended solids figures vary from this pattern. Suspended solids contributions at Tilly(P6), Jordan (P1) and the Convent (P5) are much smaller in relationship to their respective flows. Route 9 (P2), Locust Street (P3) and Anna Street (P4) share higher percentages of the suspended solids contributions.

There are other factors that may be important in dictating the distribution of solids loadings. Some of these factors can be associated with land forms such as swampy areas which can remove suspended materials before they reach the lake. There are numerous small ponds in the watershed which may be acting as sedimentation basins and remove solids before they reach Lake Quinsigamond. Jordan Pond is an example. The pond did not overflow during the summer or fall and obviously was an effective device for preventing materials from reaching the lake during the critical summer periods. Other ponds may have similar effects although the residence times are generally short and it is questionable if much sedimentation is occurring. Ponds such as City Farm on Poor Farm Brook, Newton Pond, and Old Mill Pond on Tilly Brook may be removing solids in storm flows before they reach the lake. In general it is the lower-sloped areas that have the

TABLE III-23

Loading Distribution at Monitored Sites

(percentage of total monitored load)*

	Jordan Pond P1	RT.9 P2	Locust St. P3	Anna Street P4	Convent P5	Tilly P6
Flow	4	14	7	18	7	50
TSS	2	28	12	19	2	36
Total Nitrogen	7	25	9	15	5	38
Dissolved Phosphorus	4	13	8	19	5	49
Total Phosphorus	3	25	15	21	5	31

* This table presents the percentage distribution of average storm loads between the six primary sampling stations. The loads are the average load per storm of the monitored storm events. The total of all the loads (100%) is the average total load monitored at the six stations, not the total load reaching the lake from all sources.

As catchment sizes vary for each sampling station, the flow contribution at each station also varies substantially. The intention of the table is to demonstrate how solids related pollutants do not follow the distribution patterns for flow, whereas dissolved pollutants do have similar distribution to flow.

additional benefit of ponds and wetland areas to reduce solids loadings.

Nutrients

Nutrient loadings were determined by the lake analysis to be the key to dissolved oxygen levels in the hypolimnion. The nutrients were determined to be more important than direct oxygen-demanding loads. Nutrients impact dissolved oxygen by feeding algal populations which impact dissolved oxygen through the processes of respiration and decay.

Dissolved phosphorus was identified as the nutrient limiting algal growth in most situations. Particulate phosphorus loading contributes to the problem directly, and may be more important than presently identified by regeneration of sediment phosphorus through aquatic plant decay. Nitrogen loads may also be important for short periods in the summer when nitrogen may become the limiting nutrient (as opposed to phosphorus).

The particulate phosphorus loadings follow the same distributions pattern identified for suspended solids. The ratio of total phosphorus to dissolved phosphorus is 4.2:1 for total tributary loads and 5.2:1 for storm loads. These ratios illustrate that the greatest amount of phosphorus is associated with particulates. Examination of Table III-23 demonstrates that the total phosphorus loadings for storm runoff (total phosphorus is primarily composed of particulate phosphorus) follows the same pattern as suspended solids. The steeper-sloped Worcester stations (Route 9-P2, Locust Street-P3, Anna Street-P4) contributed higher proportions of total phosphorus than their respective flow contributions. The remaining lower-sloped areas contributed lower proportions of total phosphorus.

The distribution of dissolved phosphorus does not follow the distributional pattern identified for solids. As Table III-23 demonstrates the dissolved phosphorus loads closely follow flow for the six monitored stations irregardless of the dynamics of the flows. Dissolved phosphorus concentrations are uniform in runoff from different areas. As a result the total phosphorus: dissolved phosphorus ratios are high for the three high slope stations (7.0 for Route 9, 6.7 for Locust (P3) and 3.9 for Anna Street). For the other stations the total phosphorus: dissolved phosphorus concentrations are lower (2.4:for Jordan, 3.5: for the Convent, and 2.2: for Tilly Brook). No pronounced impact on dissolved phosphorus loading can be discerned from the data as originating in a unique portion of the watershed. Although urban land uses have been shown to have a greater dissolved phosphorus loading per acre, the loading closely follows the amount of flow that can be generated per acre.

Plotted concentration values demonstrate first flush occurs at all stations for solids. In particular, total phosphorus concentrations are shown to be higher in the first few samples after the start of a rain event. On the other hand, dissolved phosphorus does not show any first flush. Concentrations remain fairly constant throughout the course of the rain event. These qualitative distinctions suggest very different sources of the dissolved and particulate phosphorus. In particular, because of the lack of a first flush in dissolved phosphorus it does not appear that sediments transportable by a storm are major sources of dissolved phosphorus.

Settling column results at Route 9 and Anna Street show moderate settling potential for particulate phosphorus. Only approximately 20% of the total phosphorus was seen to settle over the course of the column test which distinguishes particle settling rates as low as 0.001 cm/sec. As the total phosphorus: dissolved phosphorus ratios for Route 9 and Anna Street are greater than 5, higher settling rates would be expected than were seen in the settling column results. However, the two storms sampled for settling column tests were not major storms and may not have generated heavy sediment loadings.

The total nitrogen loading pattern lies in between the dissolved phosphorus and sediment patterns. Only about 50% of the total nitrogen reaching the lake is delivered by storm flows. Table III-23 suggests that total nitrogen loadings fairly well follow flows, although loadings are somewhat heavier on the Worcester side. A slight to no "first flush" can be discerned from the concentration time plots. No settling was discerned for nitrogen from the settling column results. These results are as expected as nitrogen is typically in a dissolved form or a relatively unstable particulate form. Control of total nitrogen through particulate control is less favorable than control of total phosphorus through particulate control.

Heavy Metals

The sediment data indicates that selected heavy metals are deposited in significant amounts in the lake bottom. Heavy metals from there can be introduced into the food chain by the low oxygen and low pH conditions favoring dissolution of heavy metals. The extent of heavy metals recycling through the lake's ecosystem is not known.

Overall heavy metal loadings of toxic heavy metals are light. There are heavier loadings of iron which is a characteristic of the iron-rich watershed. Lead is also relatively heavy in the sections of the watershed where automobile traffic is heavy. Short periods of high metals concentrations were seen at the start of rain events at monitoring sights on the west side of the Lake (Anna Street, Route 9, Locust Street, Convent), and at Jordan Pond on the east side probably due to the portion of Route 9 that it drains. Heavy metal concentrations were consistently low at Tilly Brook.

Bacterial-Related Pollution

High fecal coliform levels were observed at all water quality monitoring stations except at the Convent. In all cases samples were taken with fecals in excess of 10^4 counts per 100 ml with conditions probably the worst in samples from the Belmont Street storm drains (Route 9). These high levels indicate sewage contamination is occurring in all the catchments monitored with the exception of the commercial area monitored at the Convent (P5).

The sources of the sewage contamination are likely to be numerous. In areas without sanitary sewers, septic tank leaks may be substantial. In areas with sewers, house connections have increasingly been identified as a source of sewage contamination. In general, storm drains are constructed without a great deal of care to avoid infiltration, and renegade sewage leaking from house connections has no difficulty reaching the storm drains. Additionally there may still be direct sewage connections draining to storm drains or major points of leakage between neighboring sanitary and storm lines. Common manholes were a problem in the past and may still be allowing some leakage.

The lake monitoring results show high bacteria concentrations in the vicinity of Route 9 and in the northern basin. The presence of high fecal coliform levels in the storm drains on both sides of the lake near Route 9 is unquestionably causing the high values after storms. The high levels in the northern basin in general may be caused more by Poor Farm and Coal Mine Brooks where there are known sewage contamination sources.

d. Lake Response to Alternative Loading Projections

Lake response to nutrient loadings vary over a continuous scale and it is difficult and possibly misleading to select a particular number or concentration as a single water quality objective. One general objective might be to prevent future degradation of the lake resulting from changes in land use or other loading factors. A management strategy might be to minimize the available phosphorus loading and in-lake concentration, while weighing the costs of control against the water quality benefits. A few water quality milestones can be defined to aid in this process.

One milestone is the state guideline of a 4-foot (1.22 meter) Secchi depth for bathing, based upon safety considerations. Both the monitoring data and simulations indicate that both lakeshave consistently satisfied this criterion. While this objective is currently satisfied, except possibly in certain areas following storm events, management strategies should recognize the possibilities for violating it at some time in the future, as a

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result of changing land use and/or practices which influence nutrient and/or suspended solids loading.

Another potential objective is related to lake oxygen status. Roughly 200 days of oxygen supply are needed in the hypolimnion at spring turnover, in order to maintain aerobic conditions during the thermally stratified period. Aerobic conditions would reduce the potential for releases of nutrients and metals from bottom sediments and extend fisheries habitat. Data and simulations indicate that under existing land uses, the lake's oxygen supply averages 149 days (range 110-215), based upon 12-years of simulated loadings. Thus, reductions in available phosphorus loading would be needed in order to achieve this objective, which is consistent with an average available phosphorus concentration of about 11 mg/m3, compared with the existing average of about 16 mg/m3.

Achieving the above oxygen supply objective would increase the percent of the hypolimnion available as cold-water fish habitat in late summer from 0% under current conditions to about 25%. The late-summer, cold-water fish habitat is limited to the metalimnion (20-30 feet) under existing conditions. Assuming that the thickness of the layer satisfying the cold-water, high oxygen objective is between 5 and 10 feet, trout space is limited to between 1.5 and 3.1 million cubic meters under existing conditions. Adding 25% of the hypolimnion (1.4 million cubic meters), would bring the total to between 2.9 and 4.5 million cubic meters, an increase of between 45% and 93%. Associated with this volume increase, and perhaps more important, would be reductions in hypolimnetic ammonia concentrations. The general response to increased oxygen supply would be improved summer habitat for stocked trout and the potential for a substantial increase in the native population.

Other benefits of reduced phosphorus loading would include a reduction in occurrence of blue-green algae. Under current conditions, the lake becomes nitrogen limited and blue-green algal types become dominant in late summer.

This results primarily from the fact that, compared with base flows, urban runoff is rich in phosphorus relative to nitrogen and algal growth requirements. Urban runoff provides an intermittent nutrient supply throughout the summer, while nitrogen-rich base flows subside after spring. A reduction in phosphorus loading would cause phosphorus-limited conditions to persist later in the summer and reduce the selective pressure for blue-greens. Blue-green algae are generally less desirable than greens of diatoms for many reasons relating to aesthetics, health,and fisheries.

To provide some perspective on how future land use changes and possible control options might influence lake water quality, model simulations have been done for each of 5 scenarios:

(1) current land uses, current control practices;
(2) future land uses, current control practices;
(3) future land uses, 50% reduction in runoff particulates;
(4) future land uses, 50% reduction in runoff volume; and
(5) future land uses, 75% particulate control, 50% runoff volume control

The water quality model has been applied to each scenario using twelve years of simulated loadings provided by Environmental Design and Planning,Incorporated. Tables III-24, 25 and 26 list the means and ranges of water quality responses under each plan,assuming 0%, 10% and 20% availability of particulate phosphorus, respectively. Data indicate that the 10% value is the most likely, although the other values are within the feasible range.

Comparing the first two scenarios provides a basis to estimate how future changes in land use might affect water quality, if current control practices are not changed. The simulations assume that future development is similar to that existing with respect to the factors which control runoff loadings within each land use category. The means of most water quality variables are changed by roughly 12-14%, resulting from the increased nutrient and suspended solids loadings. Thus, control options designed to prevent water quality degradation would have to reduce future loadings of suspended solids and available phosphorus by 12-14%.

Table III-24
Simulation of Alternative Land Uses and Management Strategies Assuming 0 % Particulate Phosphorus Availablility

Land Use: Strategy:*		present A	future A	future B	future C	future D
Available P (mg/m3)	min **	12	12	12	10	10
	mean	16	17	17	14	14
	max	21	22	22	18	18
Trophic State Index	min	34	34	34	37	37
	mean	40	41	41	31	31
	max	46	46	46	43	43
Chlorophyll-a (mg/m3)	min	2.6	2.6	2.6	2.1	2.1
	mean	4.2	4.5	4.5	3.3	3.3
	max	5.9	6.2	6.2	4.8	4.8
Secchi Depth (m)	min	1.9	1.8	2.1	2.3	2.6
	mean	2.4	2.2	2.6	3.0	3.2
	max	3.4	3.3	3.6	3.8	3.9
Days of Oxygen Supply (days)	min	112	108	108	129	129
	mean	146	140	140	169	169
	max	194	196	196	223	223
Trout Space	min	.00	.00	.00	.00	.00
	mean	.03	.02	.02	.10	.10
	max	.21	.21	.21	.33	.33
N/P ratio	min	29	29	26	36	34
	mean	34	34	32	40	39
	max	41	42	41	46	46
Suspended Solids (mg/m3)	min	.7	.8	.5	.5	.3
	mean	1.6	2.0	1.0	1.0	.6
	max	2.4	2.9	1.5	1.5	.9

* Strategies:

A = current conditions
B = 50% reduction in particulates (runoff treatment)
C = 50% reduction in surface runoff volumes and loadings (through watershed management)
D = both B and C combined, i.e. 75% particulate control, 50% dissolved loading control, 50% runoff reduction

** Statistics based upon 12 years of simulated loadings

Table III-25
Simulation of Alternative Land Uses and Management Strategies
Assuming 10% Particulate Phosphorus Availablility

Land Use:		present	future	future	future	future
Strategy:*		A	A	B	C	D
Available P (mg/m3)	min **	11	11	10	9	9
	mean	16	18	16	13	12
	max	22	23	21	18	17
Trophic State Index	min	32	32	31	29	27
	mean	40	41	39	35	34
	max	46	48	45	42	41
Chlorophyll-a (mg/m3)	min	2.3	2.3	2.1	1.8	1.7
	mean	4.1	4.6	3.9	3.1	2.8
	max	6.1	6.8	5.8	4.7	4.2
Secchi Depth (m)	min	1.9	1.7	2.1	2.3	2.7
	mean	2.5	2.2	2.8	3.0	3.4
	max	3.6	3.4	3.8	4.0	4.3
Days of Oxygen Supply (days)	min	110	102	113	131	140
	mean	149	138	155	182	196
	max	215	209	226	247	263
Trout Space	min	.00	.00	.00	.00	.00
	mean	.05	.03	.06	.14	.20
	max	.30	.27	.34	.41	.46
N/P ratio	min	29	27	30	37	40
	mean	35	33	36	43	45
	max	46	45	48	53	55
Suspended Solids (mg/m3)	min	.7	.8	.5	.5	.3
	mean	1.6	2.0	1.0	1.1	.6
	max	2.4	2.9	1.5	1.6	.9

* Strategies:

A = current conditions
B = 50% reduction in particulates (runoff treatment)
C = 50% reduction in surface runoff volumes and loadings
(through watershed management)
D = both B and C combined, i.e. 75% particulate control
50% dissolved loading and surface runoff control

** Statistics based upon 12 years of simulated loadings

Table III-26
Simulation of Alternative Land Uses and Management Strategies
Assuming 20% Particulate Phosphorus Availablility

Land Use: Strategy:*		present A	future A	future B	future C	future D
Available P (mg/m3)	min **	10	10	9	8	8
	mean	16	18	15	13	11
	max	22	24	20	18	16
Trophic State Index	min	30	31	29	27	25
	mean	40	42	38	35	32
	max	46	48	45	42	40
Chlorophyll-a (mg/m3)	min	2.0	2.2	1.8	1.6	1.4
	mean	4.1	4.7	3.6	2.9	2.4
	max	6.2	7.2	5.5	4.6	3.8
Secchi Depth (m)	min	1.9	1.7	2.2	2.4	2.8
	mean	2.5	2.2	2.9	3.0	3.6
	max	3.7	3.5	4.0	4.1	4.5
Days of Oxygen Supply (days)	min	108	98	117	132	149
	mean	151	137	166	189	215
	max	230	218	250	268	293
Trout Space	min	.00	.00	.00	.00	.00
	mean	.05	.03	.09	.17	.27
	max	.36	.31	.42	.48	.55
N/P ratio	min	29	27	32	38	45
	mean	35	33	38	44	50
	max	49	47	53	58	63
Suspended Solids (mg/m3)	min	.7	.8	.5	.5	.3
	mean	1.6	2.0	1.0	1.1	.6
	max	2.4	2.9	1.5	1.6	.9

* Strategies:
A = current conditions
B = 50% reduction in particulates (runoff treatment)
C = 50% reduction in surface runoff volumes and loadings (through watershed management)
D = both B and C combined, i.e. 75% removal of particulates 50% reduction in dissolved loadings and runoff volumes

** Statistics based upon 12 years of simulated loadings

The third scenario assumes that 50% of the suspended solids and particulate phosphorus loadings under future land uses are removed. Possible methods might include increased street sweeping, watershed management to reduce erosion, and runoff treatment to remove suspended solids. Water quality improvements are apparent for transparency and suspended solids, although effects on phosphorus, chlorophyll-a and oxygen supply are small because of the importance of the uncontrolled dissolved phosphorus loading.

The fourth scenario assumes 50% reduction in runoff volume, which causes proportionate reductions in both dissolved and particulate loadings in surface runoff. To maintain a water balance, the reduced volume is assumed to cause increased base flow, with base flow nutrient and suspended solids concentrations constant. This plan might involve various watershed management practices which are designed to reduce runoff and increase stormwater infiltration (e.g., porous pavement, buffer strips, erosion controls, recharge basins, planning to minimize impervious areas in new and/or renewed developments). Diversion of surface runoff out of the basin is another approach, which would be somewhat more effective at reducing loadings (because reductions would not contribute to base flow), but at a loss of water to the basin. For most variables, this scenario results in average water quality conditions which are roughly 20-30% improved over existing conditions and land uses.

The last scenario represents a combination of particulate loading controls and surface runoff reduction. Assuming the most likely particulate phosphorus availability ratio (.1), this plan would result in an increase in the hypolimnetic oxygen supply from an average of 149 days under current conditions to 196 days, close to the 200-day objective discussed above. Suspended solids concentrations (and lake sedimentation rates) would be reduced by an average 62%, while transparency would be increased by 36%.

Based upon the loading models summarized above, the available phosphorus loadings corresponding to the oxygen status milestone are summarized in Table III-27 for the mean and range of outflow regimes that have been simulated. Calculations

Table III-27
Available Phosphorus Loadings Consistent with 200 Days of Hypolimnetic Oxygen Supply

	Hydrologic Year		
Component *	Dry (1965)	Average mean	Wet (1972)
Total Outflow	12.6	30.6	53.8
Surface Runoff	7.9	12.2	19.6
Excess Precip.	1.3	1.3	1.3
Base Flow	3.4	17.1	32.9
Fa=0.0			
Available P Load	727	987	1257
Atmospheric Load	88	88	88
Estimated Base Load	92	462	888
Allowable Runoff Load	547	437	281
Existing Total Load	818 (12%)**	1360 (27%)	2203 (43%)
Existing Runoff Load	638 (14%)	810 (46%)	1227 (77%)
Future Total Load	891 (18%)	1420 (30%)	2301 (45%)
Future Runoff Load	711 (23%)	870 (50%)	1325 (79%)
Fa=0.1			
Allowable Available P Load	934	1195	1464
Atmospheric Load	88	88	88
Estimated Base Load	98	491	944
Allowable Runoff Load	748	616	432
Existing Total Load	1092 (14%)	1720 (31%)	2758 (47%)
Existing Runoff Load	906 (17%)	1141 (46%)	1726 (75%)
Future Total Load	1232 (24%)	1868 (36%)	2989 (51%)
Future Runoff Load	1046 (28%)	1289 (52%)	1958 (78%)
Fa=0.2			
Allowable Available P Load	1257	1464	1731
Atmospheric Load	88	88	88
Estimated Base Load	103	520	1000
Allowable Runoff Load	1066	856	643
Existing Total Load	1365 (8%)	2081 (30%)	3314 (48%)
Existing Runoff Load	1174 (9%)	1473 (42%)	2226 (71%)
Future Total Load	1573 (20%)	2316 (37%)	3679 (53%)
Future Runoff Load	1382 (23%)	1708 (50%)	2591 (75%)

* flows in hm3/yr, loads in kg/yr;

** percent reduction in loading required to achieve objective; "existing" and "future" refer to land use distributions; Fa = assumed particulate phosphorus availablility ratio are presented for each of three assumed particulate phosphorus availability ratios: 0, 0.1 and 0.2. Allowable loadings are compared with those calculated for present land uses and for future land uses. Results indicate that it would be more difficult to meet the objective during wet years, as compared with dry years, owing to the greater significance of the base load component and lower hydraulic residence time of the lakes during wet years. Under future land uses, for example, 23%, 50%, and 79% of the surface runoff available phosphorus loadings would have to be controlled in order to meet the oxygen status objective in a dry, average, and wet year, respectively. Expressed on a percentage basis, control requirements are nearly independent of assumed availability ratios.

Table III-28 demonstrates that, while control objectives are independent of the availability ratio, the selected control method may critically depend upon the assumed Fa value. Generally, "end-of-pipe", or runoff treatment methods are more feasible for particulate than for dissolved loading fractions. For an average hydrologic year under future land use conditions and assuming complete control of the particulate loading component, control requirements for the dissolved fraction are 50%, 29% or 2%, for assumed availability ratios of 0,0.1 and 0.2. Meeting the objective during wet years would require control of between 51% and 79% of the dissolved loading component. Direct measurements of sediment phosphorus availability would be needed to aid in the final design of any program to control particulate phosphorus loadings.

The above simulations are intended to illustrate the sensitivity of lake water quality to land use changes and typical control options. The effects of specific control options implemented in certain areas could be evaluated in detail using the modelling framework developed and demonstrated above. Generally, the importance of dissolved phosphorus loading is the key factor which should be considered in designing management strategies.

While studies have shown that street sweeping has minimal effectiveness for controlling dissolved phosphorus originating in accumulated dust and dirt,

Table III-28
Sensitivitity of Potential Phosphorus Control Strategies to
Assumed Particulate Phosphorus Availability

Component	Hydrologic Year Dry (1965)	Average mean	Wet (1972)
Fa = .0			
Required Reduction *	23%	50%	79%
Particulate Component	0%	0%	0%
Dissolved Reduct. Req.**	23%	50%	79%
Fa = .1			
Required Reduction	28%	52%	78%
Particulate Component	32%	32%	32%
Dissolved Reduct. Req.	0	29%	68%
Fa = .2			
Required Reduction	23%	50%	75%
Particulate Component	49%	49%	49%
Dissolved Reduct. Req.	0	2%	51%

* percent reduction in surface runoff component of available P loading required to meet 200 TDO objective (see Table III-27)

** percent reduction in dissolved, surface runoff component of available P loading required to meet objective, assuming complete control of surface runoff particulates leachate from leaves accumulating on impervious areas has been identified as one potentially significant source of dissolved phosphorus in urban runoff. Because of the diffuse and uncontrollable nature of many of the other dissolved phosphorus sources in the urban environment (e.g., rainfall, dustfall, animals, traffic), management practices and designs which encourage water infiltration (hence natural phosphorus removal in the soil column) would generally be the most effective at controlling the eutrophication of Lake Quinsigamond. Higher runoff reduction or runoff treatment could be used to reduce lake sedimentation and turbidity resulting from particulate loadings. Because of the sedimentation and aquatic weed population in Flint Pond, however, in-lake restoration techniques, such as draw-down and dredging, may be required along with loading controls to substantially improve conditions. The viability, feasibility, and costs of these techniques have yet to be evaluated.

Conclusions

Based upon the preceding assessment of pollution sources, water quality impacts,and receiving water response to projected pollutant loading, the following conclusions can be drawn:

1. Stormwater runoff in the Lake Quinsigamond watershed is a major source of pollution. The pollution is most extensive for particulates and for parameters associated with particulate solids. The generation of sand bars and filling-in of shallow water areas is extensive. Pollutants such as phosphorus are associated with non-dissolved solids in high proportions. Dissolved constituents are heavily present in stormwater flows although dry weather flows also contribute significant amounts. Such pollutants as nitrogen in various forms and dissolved phosphorus are significant. Heavy metals are present in runoff in relatively small quantities. Bacteria related pollution is widespread in storm water runoff.

2. Although there is a strong negative response in the lake to stormwater loadings, Lake Quinsigamond possesses a substantial buffering capacity against stormwater pollutants. The abundance of iron to precipitate phosphorus and deep lake depths have maintained the recreational uses in the face of urbanization in the watershed. Still, dissolved oxygen problems arise in the hypolimnion as a result of nutrient loads. These problems limit the fish habitat and encourage recycling of bottom sediment metals. Bacterial pollution is evident following a storm event. Solids deposition in the areas of storm drains is causing boating hazards and esthetic concerns. Although transparency is generally good, there is a significant decrease in transparency following a rain event. Weed growth and deposition in the shallow parts of the lake and in Flint Pond are limiting recreational activities. Water transparency is reasonable, algae in the surface layers are reasonably limited, and eutrophication does not appear to be increasing except in the shallow areas where weeds dominate.

3. Dissolved phosphorus was identified as a key to the rate of eutrophication and the hypolimnetic dissolved oxygen depletion rate. Dissolved phosphorus concentrations were determined to be uniform over the watershed. Particulate phosphorus control will have only a minimal immediate impact on the dissolved oxygen problem although such control may help more in the long run by reducing sediment phosphorus and subsequent weed growth and decay. Significant improvement in hypolimnetic dissolved oxygen levels would require a 50% reduction in dissolved phosphorus which is beyond the reduction attainable through stormwater control.

4. Suspended solids and associated pollutant loadings are heaviest on the Worcester side of Lake Quinsigamond where the steeper ground slopes provide greater

scouring capacity. The wetland areas and small ponds intercepting tributary flows in other parts of the watershed may be important in reducing particulate loadings.

5. Bacterial related pollution is widespread in the watershed. Fecal coliform levels indicate that sewage contamination is still occurring throughout the watershed.

6. Anticipated future land uses are estimated to result in a 12-14% degradation in average water quality conditions, as measured by suspended solids, available phosphorus, and other eutrophication-related variables. Therefore, control of 12-14% of future available phosphorus and suspended solids loadings would be needed to maintain existing water quality.

7. Reduction of phosphorus loadings to insure 200 days of hypolimnetic dissolved oxygen supply at spring turnover is suggested as a potential water quality management objective, which would reduce the potential for internal metals and nutrient cycling, improve fish habitat, provide proportionate reductions in chlorophyll and increase water transparency.

8. Under projected future land uses, the above objective would require about a 50% reduction in loadings of available phosphorus in surface runoff during an average hydrologic year. Control requirements during wet hydrologic year would be more stringent (78%).

9. Because of the importance of dissolved phosphorus loadings, watershed management strategies for reducing runoff volumes by encouraging water infiltration should be examined along with runoff treatment schemes as a means of achieving water quality objectives.

IV. Control Alternatives

A. Introduction

There are many control alternatives that are available to deal with the problems associated with stormwater runoff. In determining which measure to employ, numerous parameters must be considered and economic factors evaluated. Actions aimed at reducing stormwater runoff before it enters the drainage system are termed source controls. Improved urban sanitation, land use planning and retention/detention systems are examples. Another approach focuses on collection system controls through actions such as catch basin maintenance and storm sewer inspection, maintenance and cleaning. Stormwater may also be treated or stored using techniques such as disinfection, and in-line (within the storm sewer) or off-line (in tanks, lagoons, or containers) storage. These treatment and abatement methods can be used not only singularly but in combination with each other to create an overall abatement program which will optimize their effectiveness by reducing pollution, enhancing aesthetic and water reuse potential and minimizing costs.

This section will serve to discuss the various control alternatives, their impacts, effectiveness and cost considerations.

Source Controls

Source controls approach stormwater management in a preventative manner by acting to reduce stormwater runoff before it enters the drainage system or surface waters. They are an efficient and economical means of reducing peak runoff flow rates which will lessen or eliminate problems of flooding, pollution, soil erosion and siltation. These controls are especially effective and applicable in developing areas where controls can be easily implemented as opposed to already existing highly developed areas.

1. Street Sweeping

Street cleaning is considered an important facet in the attempt to preserve urban water quality. The main objective of street sweeping programs is to control those types of materials which are a nuisance from the standpoint of aesthetics and public safety. As such, it does not necessarily address the finer matter which is of importance as a water pollutant.

Street sweeping is typically accomplished by manual labor, mechanical sweepers, vacuum-type sweepers or combined vacuum and mechanical broom-type sweepers. Mechanical sweepers are most commonly used. These units basically consist of a gutter and main broom which rotate at high speeds forcing the debris from the gutter and street surface onto a conveyor belt and subsequently into a hopper. Water is usually sprayed on the surface for dust control.

The effectiveness of the practice of street cleaning in removing pollutants is dependent on several factors including the sweeper efficiency, the frequency and timing of sweeping, the speed of the equipment, the number of passes, the type of equipment used, and the pavement conditions. Public awareness is important to the success of a street cleaning program in that cooperation is necessary to obtain the funds and, in addition, compliance with parking regulations facilitates more efficient street sweeping.

Street sweeping is more effective in removing total solids and suspended solids, particularly lead, than in lowering the chemical or biological demand or removing other contaminants. It reduces the particulate loadings and some dissolved loadings by reducing the amount of polluting materials available along roadways. However, the area in the Lake Quinsigamond watershed that could be swept is small. The dissolved phosphorus loadings come from the entire watershed including the more rural areas where street sweeping is impossible. The settling column tests indicated that the dust and dirt that would be swept up by a robust sweeping program is not likely to be a significant source of dissolved phosphorus. For these reasons street sweeping does not appear to be a significant means of controlling nutrient loadings.

However, for the parameters that it does remove, street sweeping is particularly cost effective, representing a much lower cost ($/lb removed) for certain substances than would be required if these contaminants reached the runoff and had to be treated accordingly. The capital cost of street sweeping is low relative to other management alterntives, particularly in view of the fact that most towns already own the machinery. The costs increase over present levels when the frequency of the sweeping is increased to reach higher levels of pollution abatement. These increased costs are considered 'socially beneficial' in that such labor intensive operations are preferable to operations that are equally cost effective but require more investment in materials and less in employment.

Conventional sweeping costs reported in dollars/curb/mile vary widely. Costs have been reported to range from a low of $2.18 to a high of $12.24. The variation between the rates is considered to be due to labor rates, unionization of employees and equipment costs.

It has been estimated that street sweeping costs per ton of solids removed are about half the costs for solids removed via the sewerage system.

To produce an overall improvement in the collection of street surface contaminants and to collect fine matter, the following list of management practices should be considered (Sartor and Boyd, November 1972):

- Promote more effective training of equipment operators.
- Place limits on equipment operating speeds.
- Maintain accurate and detailed records of street cleaning operations in order to evaluate effectiveness and to make any adjustments that might be necessary.
- Maintain pavements in good condition with increased attention being directed toward the differences between asphalt and concrete and the effects they have on loose particulate matter on the streets.
- Good routine maintenance schedules should be implemented, including proper adjustments to equipment operating parameters as

specified in owner's and operating manuals to keep equipment functioning at peak efficiency.

- Adopt and/or enforce no parking ordinances effective on street sweeping days.

These management practices do not involve the construction of facilities or the acquisition of land and can be applied to most urban areas in the watershed with a minimal number of problems.

The extensive parking lot systems located throughout the watershed would also benefit from a sweeping program. Prime target areas include the University of Massachusetts Medical School with approximately nine acres of parking lot, the section of Tilly Brook adjacent to Spag's and the Wyman Gordon Company parking lots located on Bonnie Brook.

2. Deicing Management

Management of highway deicing practices and salt storage sites are particularly relevant to stormwater runoff control practices. Typical deicing practices contribute considerable chloride loads represented by increases of 40 - 50% during the winter months while sanding adds considerable loads of suspended solids. The additional suspended solids cause problems in catch basins, and storm and combined sewers and require treatment later. Chemical additives to the deicing materials include cyanide, phosphate and chromium which result in polluted snowmelt and contamination of receiving waters. In addition, these additives which act as anticaking agents and corrosion inhibitors may have severe latent toxic properties. Sodium ferrocyanide, for example, minimizes the caking of salt but is soluble in water and will release cyanide in the presence of sunlight.

The following practices should be considered when evaluating deicing programs:

1. Apply salt and abrasives judiciously.
   - Limit application to critical locations such as curves or hills.
   - Maintain records of salt use.

- Instruct operators as to the most efficient rate of salt application that will facilitate melting but at the same time minimize environmental impacts.
- Calibrate and maintain spreading and metering equipment in excellent condition to ensure even applications.

2. Prohibit the use of chemical additives.
3. Use substitute deicing compounds; for example, calcium chloride which has a lower corrosive effect but a higher cost.
4. Educate the public and operators about the effects of deicing technology and best management practices.
5. Provide specific salt storage areas on flat and impervious surfaces which are designed and intended for that purpose to protect from runoff and subsequent leaching.
6. Do not store salt in the immediate vicinity of wells, surface waterbodies or in aquifer recharge areas.
7. Dispose of plowed snow which has been treated with salt in an area which will not contaminate water supplies. Direct dumping into surface waters or over an aquifer should be prohibited.

The cost of implementing these recommended practices is relatively low especially when considering the positive effects on groundwater quality, health, vegetation and reduced corrosion damage to highway structures and vehicles.

Additional methods that would reduce the pollution of runoff due to deicing compounds are listed below.

1. In-slab thermal melting which involves the construction or addition of heating elements into street and highway surfaces;
2. Stationary/mobile snow melters which consist of a variety of processes from scrapers and melters to fixed heating units such as blowers or heating coils;
3. Compressed air types of snowplows;
4. Adhesion reducing pavement materials which can be used for the construction of road surfaces or applied to reduce snow and ice from adhering to the surface making their removal easier and more efficient;
5. Solar energy storing pavement substances; and
6. Electromagnetic ice shatterers.

Implementation of these methods, however, would require considerable capital outlays and/or construction and may not be cost effective.

3. Land Use Planning

Source controls include land development regulations and water quality management techniques to control and prevent potential sources of pollution. Land use control through zoning regulations provides a necessary mechanism for controlling developments to safeguard against further detrimental effects of urbanization. Impacts of various land use practices must be considered and zoning regulations designed and enforced accordingly. It is essential for the success of such a program that consistent standards be used to evaluate the applications and strict enforcement of the regulations be practiced.

Zoning regulations may be designed according to natural feature districts, use and density criterion, performance standards or growth management standards.

a. Natural Feature Districts

Zoning regulations designed according to natural features districts recognize and protect the areas which have a direct relationship to the protection and maintenance of water quality. Typical districts which are designated for protection include wetlands districts, floodplains districts, aquifer recharge districts, stream buffers, watershed protection districts and water resource protection districts. These zoning regulations are designed to ensure that the critical natural functions of the districts will be maintained and that intensive site modification will be prohibited.

Wetlands

Wetlands are wet, vegetated areas such as bogs, swamps or marshes. These areas are complex hydrological, chemical and biological systems which serve several important functions. They represent an excellent wildlife habitat in providing spawning grounds for several species of fish as well as nesting areas for ducks and other waterfowl. They serve as a natural mechanism for minimizing water level fluctuations by taking up water during wet periods and gradually releasing it. Flow velocities through wetland systems are usually low permitting a natural filtering function to occur with a large portion of the suspended particulate materials settling out instead of being transported downstream. The fibrous organic soil found in this type of ecosystem will hold nutrients until microbial utilization occurs. The levels of photosynthesis are characteristically high in wetlands and nutrients will be incorporated into plant tissue. The denitrification reactions which occur will remove nitrogen from the water and soil releasing it into the atmosphere.

Specific areas within the watershed that benefit from these natural functions and therefore should be preserved include the wetlands located in the northern portion of Sewall Pond, the South Meadow Brook marsh, and the Slocum Meadow marsh. To preserve and protect these areas, activities such as filling, dumping, dredging, paving and construction which would result in extensive site modification should be prohibited. The storage of chemicals, salt or petroleum products should also be prohibited. This land is an excellent choice for conservation; recreational activities such as hunting, fishing, hiking, etc; and agricultural activities which do not require fertilizers or pesticides.

Floodplains

A floodplain is an area adjoining surface waters which has the potential to be covered by flood waters. Floodplains operate to retain the natural storage capacity of the watershed, preserve the water table and recharge area, and provide for the continued functioning of the ecosystem.

The purpose of floodplain zoning is to avoid encroachment on the floodplain and to protect public safety by providing natural storage areas for floodwaters. At the same time these measures will lessen the potential for water quality degradation.

Aquifers

An aquifer has been defined as a geologic formation that contains sufficient saturated permeable material to yield significant amounts of potentially potable water. In order to prevent public wells from becoming polluted, it is necessary to protect the entire aquifer and its recharge area. The recharge area may consist of stratified sand and gravel and wetlands which collect rain or surface water and carry it to aquifers. Certain activities should be prohibited within the recharge area such as the siting of landfills or earth removal unless restricted to areas several feet above the spring high-water table. Storage and use of gas, oil and deicing salts should be carefully regulated. Since drainage is of particular importance, porous pavement or gravel driveways, open watercourses, recharge basins and dry wells should be integrated into the recharge district. A buffer area to preserve water quality should be provided within 400 feet of a gravel-packed well and 250 feet from a tubular well.

Stream Buffers

Stream buffers adjacent to water courses and waterbodies serve in both a filtration and purification capacity. Regulations to protect and maintain these vital areas would prohibit activities which disrupt the soil, vegetation or the bank of a stream or lake. Also prohibited would be any activity which would pollute the water biologically, chemically, or physically.

Watershed and Water Resource Protection Districts

Watershed protection and water resource protection districts are created to form comprehensive zoning districts which will focus on protecting water resources from detrimental land use and development.

The formation of a watershed protection district will act to protect lakes and ponds by regulating development in the immediate watershed of these water bodies. In a water resource protection district, wetlands, floodplains, aquifer recharge areas, buffers and watersheds are all included in a comprehensive water resource protection district to protect the system of surface and groundwater from adverse water quality impacts.

b. Use and Density Regulations

Use and density regulations are designed using the natural capacity of the land as the basis for requirements. Minimum lot size, waste disposal facility availability and water supply availability is determined and regulated according to the natural limits of the land.

Cluster and Planned-Unit Development (PUD) regulations are specific zoning regulations designed with environmental considerations as the primary concern. Cluster zoning allows the overall density of a development to remain constant, but the housing units are grouped together in one portion of area while a significant portion of the land remains undeveloped. This permits environmentally sensitive areas such as wetlands, steep slopes and outcrops of bedrock to remain undeveloped. At the same time the more permeable soils may be used for the septic system for the entire development,with the additional advantage of requiring fewer access roads and shorter driveways, are required thus minimizing the amount of impervious surface.

PUD offers similar advantages but allows some commercial or light industrial activities along with the residential land use.

c. Performance Standard Regulations

Performance standard regulations are designed with emphasis on regulating the effect of the land use rather than regulating the land use itself. The offensive characteristic of a particular land use is banned rather than prohibiting the land use totally. Each case is studied individually and the land use accepted or denied depending on the offensive characteristic.

Criterion used to determine the acceptability of a particular land use might include smoke emissions, noise pollution, vibration levels, dust and other particulate matter, odor, toxic and noxious matter concentrations, fire and explosive hazards, humidity levels, heat and glare levels, radiation hazards, landscaping effects, parking availability, traffic generation, economic impacts or water quality degradation.

d. Growth Management Regulations

Growth management regulations are designed to consider the overall impact of additional development on the function and organization of the community. Development is guarded and regulated at a rate which does not place undue burdens on municipal services and reduces the financial pressures imposed on individuals of the town as a result of these additional burdens. In addition to regulating the amount of development allowed, growth management regulations take into account the timing and sequencing of developments in a long-term comprehensive plan for a given town.

e. Subdivision Regulations

A subdivision is the division of a tract of land into two or more lots. Under subdivision rules and regulations the planning board has control over the design and construction of ways, drainage and utilities. The planning board does not have the authority to regulate uses of land and siting of buildings, rather its concentration is on the design and impact within the subdivision of the previously mentioned features. The planning board has the power to adopt techniques which will protect the environment including water resources. For example, regulations pertaining to ways may contain detailed requirements as to design, grades, contours, grading of shoulders and provisions for grass strips. Amendments can be made to the subdivision regulations which will lessen the impact of urban runoff by acting to reduce the total amount of impervious surface and to encourage maximum use of natural drainage patterns.

The 'costs' of these alternatives are minimal although the denial of the economic potenial of additional developments may be considered a loss to the community that must be weighed against the long-term environmental gains. Objections may arise from individual developers but these should not be allowed to overrule the rational, practical planning of the community as a whole.

4. Ordinances and Regulations

Ordinances and regulations may be directed toward the control of pollutants that are generated by the everyday activities of people in urban areas. The cost of implementation is minimal but their effectiveness is dependent to a great extent on the degree to which they will be enforced.

a. Street Litter

Street litter includes discarded food and beverage containers, newspapers, cigarettes, lawn trimmings, and sidewalk sweepings. Unless this material is removed by street sweeping it will find its way to stormwater discharges.

Efforts by members of the community to cut litter and minimize debris could improve this situation at no cost at all. Waste disposal containers placed in convenient locations and a conscious effort by citizens to properly dispose of trash would reduce the load of pollutants somewhat. Strict enforcement of anti-littering laws and public education programs would be instrumental in this respect.

b. Leaf Pickup

Leaf pickup and removal should be advocated and the burning or storing of leaves in gutters should be discouraged since leaves can contribute significant amounts of phosphorus to urban runoff.

c. Pet Control

Ordinances to encourage owners to exercise control over pets and their wastes will reduce this source of bacterial-related pollution and BOD.

d. Chemical Control

Educational programs can be instituted to reduce the indiscriminate use and disposal of substances such as fertilizers, pesticides, oil, gasoline and detergents. The public can be made aware of the adverse effect on receiving waters due to overfertilization to promote luxuriant lawns and gardens. At the same time, instruction can be provided as to the proper storage, use and application of fertilizers. The dumping of chemicals, oil and debris directly into catch basins, inlets and sewers may also be addressed by educational programs as well as by ordinances and strict enforcement.

5. Retention/Detention Systems

Retention/detention systems are a means of collecting stormwater before it enters the collection system or surface waters. Water quality and quantity benefits may be gained by the use of either natural areas or man-made structures such as detention basins, infiltration trenches, parking lots, and roof tops. Natural depressions, swales and wetlands are a means of preserving the environment as well as providing an attractive area for stormwater storage. The advantages of using retention/detention systems include downstream flooding is reduced, dry-weather flows in rivers and streams are maintained thereby protecting wildlife habitats, sediments and pollutants are allowed to settle out from the stormwater, groundwater supplies are recharged, and the potential for erosion is lessened by reducing the volume and rate of runoff.

a. Detention/Retention Basins

Detention basins are utilized for the temporary storage of stormwater with a gradual release at a predetermined rate to surface waters, while retention basins are designed to hold water on a long-term or permanent basis followed by release through evaporation, plant transpiration or infiltration into the soil.

The siting of a facility is a crucial ingredient to its success. Safety of the site with regard to the health of individuals residing in the area and possible accidents due to collected water must be taken into consideration. Other factors include the possibility of mosquito breeding and algal growth.

Basins can be designed to suit various size requirements, land use types and hydraulic patterns, Use can be made of already existing natural ponds for this purpose. City Farm Pond is an excellent candidate for rehabilitation as a stormwater detention facility.

Detention basins are usually equipped with a subsurface outlet which allows stormwater to infiltrate the soil and pass through to a water body. During dry periods these areas may be used for recreational purposes especially if they have grassed bottoms. Variations on this concept include the design and construction of parking lots, driveways and rooftops for stormwater storage.

A retention basin may be designed as a structure or it may be aesthetically integrated into the surrounding environment as a small lake or pond. An outlet to provide for overflows is usually included in this type of basin.

A stormwater detention facility utilizing the natural drainage area, in this instance a floodplain, was constructed in Farmington Hills, Michigan. Construction costs as prepared by Giffels-Webster Engineers for the 19.3 acre site with (15 acres of upland) are presented in Table IV-1. Table IV-2 lists the estimated cost if a manmade basin had been constructed at the same site. BUILDER Magazine estimates the price for detention ponds to be between $4,000 to $25,000. Retention ponds could run as high as ten times that amount.

Maintenance is an essential element in the proper functioning of these types of detention facilities . Unmaintained areas can collect weeds and debris, produce odors, and present an unsightly appearance. Periodic repair, cleaning, sediment removal and cutting of weeds will preserve the facility and its effectiveness. In general, natural drainage systems require less maintenance since fewer structural features are involved. However, sediment removal is an

TABLE IV-1

SURFACE DRAINAGE SYSTEM COSTS
FLOODPLAIN DETENTION
(as built)

21" Storm Sewer	130 L.F.	@	$ 27.00	=	$ 3,510.00
18" Storm Sewer	300 L.F.	@	$ 22.00	=	6,600.00
12" Storm Sewer	560 L.F.	@	$ 17.00	=	9,520.00
34" X 53" Culverts (2)	60 L.F.	@	$127.00	=	7,620.00
Manholes	7 each	@	$700.00	=	4,900.00
Catch Bains	6 each	@	$650.00	=	3,900.00
Inlets	4 each	@	$400.00	=	1,600.00
Rear Yard Catch Basins	1 each	@	$475.00	=	475.00
21" end section	1 each	@	$105.00	=	105.00
Grouted stone riprap	50 S.Y.	@	$ 20.00	=	1,000.00
Berm		Lump Sum		=	8,500.00
		TOTAL COST			$ 47,730.00

L.F.= Linear Foot

S.Y.= Square Yard

TABLE IV-2

SURFACE DRAINAGE SYSTEM COST
CONVENTIONAL DETENTION
(hypothetical)

21" Storm Sewer	80	L.F.	@	$ 27.00	=	$ 2,160.00
18" Storm Sewer	300	L.F.	@	$ 22.00	=	6,600.00
12" Storm Sewer	660	L.F.	@	$ 17.00	=	11,220.00
Manholes	6	each	@	$700.00	=	4,200.00
Catch Basins	6	each	@	$650.00	=	3,900.00
Inlets	4	each	@	$400.00	=	1,600.00
Rear Yard Catch Basins	1	each	@	$475.00	=	475.00
21" end section	1	each	@	$105.00	=	105.00
12" end section	2	each	@	$ 90.00	=	180.00
Grouted stone riprap	50	S.Y.	@	$ 20.00	=	1,000.00
Detention area		Lump Sum			=	18,000.00
		TOTAL COST				$ 49,440 00

L.F.= Linear Foot

S.Y.= Square Yard

ongoing maintenance requirement which may need to be done every 5 to 10 years at a cost of $10,000 (1981 dollars) or more. The Southeast Michigan Council of Governments reports that annual maintenance costs average between $100-$200 per basin.

b. Parking Lot Storage

Parking lots may be constructed with rippled pavement or depressions to allow for the retention of stormwater. With pedestrian safety and convenience in mind, depressions may be located in drainage areas where restrictions such as orifice plates will cause the stored water to be slowly released into storm drains. Another option is to utilize paved areas to channel runoff to grassy strips or gravel trenches allowing ground infiltration.

The cost for incorporating these types of detention systems is often equal to or below the cost of conventional design.

c. Porous Pavement

The construction of roads and parking lots with porous asphalt pavement allows rainwater to filter through the road surface into a crushed stone base where it is temporarily stored. A four-inch pavement and a six-inch base could store 2.4 inches of runoff volume in its voids. The stored water is then reabsorbed into the soil and returned to the water table.

Several practical advantages may be gained from the use of porous pavement. Groundwater supply is enhanced while the total volume of runoff from paved areas is reduced better preserving the natural drainage pattern and relief is provided from flash flooding. Safety is improved by increased skid resistance and better visibility. Roadside vegetation may be enhanced due to the increased availability of water in the soil.

The cost of porous pavement is comparable to conventional pavement but significant economic savings may be gained through the elimination of curbs and stormwater drainage systems. In addition, it is possible to create the crushed stone drainage base using debris such as broken bricks, ceramic wastes, solidified fly ash and other solid residue.

Stability, durability and freeze-thaw tests have proven positive. However, long term tests are still required to evaluate clogging resistance and the quality of the water after filtering through the sub-base. Dirt and leaves which accumulate on the surface may be ground in by traffic closing the pores and negating the effectiveness of the design. It has not been clearly established that the filtering effect of the sub-base results in a significant improvement in the quality of runoff.

d. Rooftop Storage

Rooftops are other structures which have the potential to provide for stormwater storage. As water collects, drain rings or constricted down spouts will act to release the stored water gradually. Other advantages, in addition to delaying runoff, include a cooling effect is exerted on the building and fire protection is afforded by the potential to tap the stored roof water. Increasing the roof roughness by ripples or gravel is another method of delaying runoff, as are sod roof covers, rooftop gardens and pool storage.

With the proper design and construction, problems of leakage and structural overloading can be minimized. Provisions can be made for overflow mechanisms in the event of overloading due to a major storm.

Maintenance including the removal of debris, ice and leaves will require particular attention to avoid overflows from drain clogging.

This type of control can be integrated into the design and construction of new facilities at a minimal additional cost.

e. Infitration Trenches/Perforated Pipes

Another method utilizing the concept of detention is to route drainage from impervious surfaces to the ground for percolation. Infitration trenches back-filled with sand, stone or coarse gravel are an appropriate means of dealing with this problem in paved areas such as roadways and parking lots. Percolation tests run on the stratum at the bottom of the trench will indicate the rate of percolation and therefore the outflow rate. If the inflow is greater than the percolation rate, water may be temporarily stored in the voids of the filler material.

Measures should be taken to channel runoff to a storm collection system in the event of overflow due to clogging or a storm intensity greater than what the trench was designed to handle. Trenches can be designed and constructed with provisions for oil and grease removal along with sediment traps to remove suspended matter before discharge to the trench. The trench can also be designed with modifications for the removal of the backfill rock which can then be washed and reused or replaced with new rock.

The estimated cost for a system of this type is $2,500 per impervious acre.

6. Erosion and Sedimentation Control

Soil erosion occurs when the vegetative cover is removed and the soil is exposed to the action of rain, wind and surface water runoff. As rain falls on exposed soils, soil particles are picked up and transported to different locations. Sedimentation causes soil particles within the water to settle out. Erosion and sedimentation together cause the stripping of land forming rills and gulleys, the filling in of surface waters and water pollution. Sediments are composed of solid mineral and organic materials which can contain biological and chemical pollutants. They have the capacity to release nutrients in sufficient amounts to stimulate undesirable aquatic plant growths. Once in the water column, suspended particles block the sunlight required to carry on photosynthesis, reducing productivity. This suspended material will be deposited as sand bars or on the bottom of a waterbody covering and destroying benthic organisms, interrupting the food chain and reducing both lake storage and stream carrying capacities.

Vegetation plays a very critical role in the control of erosion. A canopy or crown is formed by vegetation which shields the surface of the soil from the impact of falling rain. In this way, the velocity of runoff is slowed allowing sediment to settle out. The root structure aerates the soil and maintains its capacity to absorb water. Roots additionally serve to bind soil particles in place, to loosen the soil thereby improving infiltration and to absorb water, thus minimizing runoff.

a. Stream Channel Maintenance

Stream channel maintenance is an important preventive practice. The maintenance of existing vegetation on stream banks is a basic tenet of erosion and sedimentation control. Streambank vegetation serves to stabilize the soil, to slow runoff reducing its erosive energy and to filter sediment from runoff. The more stable a stream, generally the greater its potential for fishing, wildlife and recreation. Actions which may result in streambank instability include channel realignment, channel constriction, sedimentation of the streambed and increases in runoff volume.

Stream channel inspection, cleaning and maintenance should be performed at regular intervals. Removal of debris and blockages will allow stream flow to be retained within the banks so that more susceptible areas will not be eroded away. This practice will prevent the addition of excessive nutrients, chemicals and other pollutants to the stream.

Specific problem areas that require cleaning and maintenance have been identified as Fitzgerald Brook at Lake Avenue, the Jordan Pond Outlet, Poor Farm Brook from City Farm Pond to Lake Quinsigamond and Coal Mine Brook at Lincoln Street and at the Notre Dame property.

b. Construction Activities

Construction can be very disruptive to the environment. Oftentimes, topsoil and vegetation are removed to allow grading and site preparation. When rainfall hits the exposed subsoil, it results in the washing away of large quantities of soil.

Steps should be taken during construction activities to prevent adverse impacts to water quality. Native vegetation should be maintained to as much an extent as possible. The length of time and the size of the area exposed should be held to a minimum. Strip construction in which alternating strips of land are worked at one time leaving the surrounding areas vegetated is a useful technique in this respect. When possible, clearing and grading of the land should be done when runoff is apt to be low such as during the summer and fall thus lessening the impact of erosion.

There are several methods which may be employed to stablize slopes. Construction slopes may be roughened and diversion terraces utilized to cause runoff to move across rather than down slopes. Grading should be kept to a minimum and slopes should be covered as soon as possible with netting, mulches, sod, or perennial grasses.

Straw bale filters located downhill from the construction site will act to reduce the velocity and thus the scouring power of runoff as well as decreasing any associated sediment loads as deposition occurs. In a situation where slopes are very steep and highly erodible, sediment basins through which flow may be diverted will act to settle out coarse material before runoff is discharged from the construction site. Other interim measures that are site specific include sandbagging or dumped rock riprap.

After the completion of construction activities, surface stabilization should be effected immediately. This usually entails the application of seed, fertilizer, mulch, sod or decorative rock.

Table IV-3 presents the costs associated with the various control measures available to deal with erosion.

c. Agricultural Activities

Agricultural activities generate both nondegradable and degradable wastes. The runoff from this type of land use can include silt, clay, fertilizers, animal wastes, crop residues, pesticides, inorganic salts and minerals.

TABLE IV-3

COSTS FOR ON-SITE EROSION CONTROL MEASURES*

METHOD	DESCRIPTION	UNIT COSTS		REMARKS
		California	Virginia	
A)CONTROL STRUCTURES				
Gravel and Earth Check Dam	Check dams are structures constructed in gullies or other small water courses to reduce velocities, promote deposition of sediment and stabilize channel grades.	$1.84-0.83/cf	-	19cf-225cf structures resp.
Rock Riprap Check Dam		$7.00-8.17/cf	$5.99-6.96/cf	56cf-300cf structures resp.
Concrete Check Dam		$22.15-8.04/cf	$20.03-$7.22/cf	51 cf-891 cf structures resp.
Concrete Chute	A channel designed to conduct runoff downslope from one elevation to another without erosion of the slope.	$32.45/ft 5.40/ft^2	$28.35/ft 4.72/ft^2	40 ft.chute, 3 ft. wide sides, 3 in. thick
Diversion Dike (Interceptor Dikes)	A small temporary ridge of soil to divert overland flow away from newly constructed, unstabilized or unprotected slopes.	$ 4.51/ft 0.48/cf	$3.70/ft 0.39/cf	405 cf dike 43 ft long
Erosion Check	Porous mat-like materials installed in slit trenches perpendicular to the direction of flow in ditches or swales to prevent the formation of rills and gullies.	$3.43/ft	$2.65/ft	150 ft jute mesh
Filter Berm(Filter Inlets)	Temporary ridges of gravel or crushed rock to retain sediment on-site by retarding and filtering runoff.	$5.50/ft 0.39/cf	$5.11/ft 0.37/cf	810 cf gravel berm
Flexible Downdrain	Conduits of heavy duty fabric or other material to conduct runoff from one elevation to another without erosion of the slope.	$7.34/ft	$7.26/ft	300 ft unit with end connections

* All costs in 1972 dollar

TABLE IV-3 (Continued)

METHOD	DESCRIPTION	UNIT COSTS California	 Virginia	REMARKS
Flexible Erosion Control Mats	Flexible fabric forms into which fluid mortar is injected. Used for channel lining,shoreline stabilization and check dams.	$1.18/ft^2$	$1.11/ft^2$	based on 33,000 ft^2 channel lining instal
Gabions	Large, multi-celled, rectangular wire mesh boxes filled with rock. When wired together they form flexible mats.	$3.34/ft^2$ 1.72/ft^2$ 1.41/ft^2$	$2.76/ft^2$ 1.54/ft^2$ 1.26/ft^2$	10 ft^2X 1 ft install 100 ft^2X1ft install 1000 ft^2X1ft install
Level Spreader	Outlets constructed at zero grade across a slope where runoff may be spread at nonerosive velocities in the form of sheet flow.	$3.80/ft 1.91/ft 1.63/ft	$3.16/ft 1.57/ft 1.36/ft	15 ft long 44 ft long 78 ft long
Sandbag barriers	Temporary barriers or diversions constructed of sandbags.	$ 3.10/bag 12.40/ft	$ 2.44/bag 9.76/ft	filling and placing 180 bags/day ~45'X4' barrier
Sectional Downdrain	Sectional conduits of pipe, metal concrete or other material to conduct runoff from one elevation to another without slope erosion.	$14.55/ft 10.91/ft	$11.85/ft 9.13/ft	44 ft unit 234 ft unit
Sediment Retention Basin	Storage areas constructed to trap and store sediment and debris produced by runoff.	$0.51-0.39/cf	$0.42-0.33/cf	earth structures 30 to 40 ft long and 6-8 ft high
Straw Bale Barriers	A temporary berm or diversion constructed of baled straw.	$3.93/ft	$3.31/ft	2 ft bales X one foot high

TABLE IV-3 (continued)

METHODS	DESCRIPTION	UNIT COSTS California	UNIT COSTS Virginia	REMARKS
B) GROUND COVERS				
Excelsior Mat	Mat of curled wood excelsior covered with kraft paper, biogradable plastic mesh or similar material.	$12,000/ac	$10,200/ac	includes seed and fertilizer
Jute Mash on One-Acre Plot	Heavy woven mesh of jute fibers.	$7,700/ac	$6,700/ac	
Straw or Hay(blower applied)	Used as a mulch product applied using mulch blowing equipment.	$1,200/ac	$1,100/ac	
Woodchips	Chips of wood used as a mulch product.	$8,000/ac	$7,200/ac	3" cover
4" square plugs of sod	A section of soil containing roots of grass or other plant.	$11,300/ac	$10,300/ac	includes seed and fertilizer
Sodding	Process of covering with sections of soil containing grass or other plants with their roots.	$14,800/ac	$14,300/ac	
Chemical Soil Stabilizer	Chemical mulch used to penetrate soil and bind soil particles in a coherent mass.	$1,300/ac	$1,250/ac	
Hydromulch	Wood fiber mulch applied in a water slurry.	$858-434/ac	$738-373/ac	1 acre-30 acre job, resp.

Sediment resulting from soil erosion is regarded as the greatest pollutant, by volume, that affects water quality.

The Soil Conservation Service and the Agriculture Stabilization and Conservation Service are federal agencies that will advise and offer technical assistance to farmers in Worcester County. The continuance of these services will not involve any additional costs and will result in positive environmental impacts including the conservation of natural resources and the attainment of water quality goals.

Some management practices and their associated costs which will alleviate water pollution problems either alone or in conjunction with each other are listed below:

Practice	Approximate Cost (1979 dollars)
Cover Crops	\$20/acre
Crop Rotations	Minimal
Contour Planting	Minimal
Strip Cropping	Minimal
Pesticide Management	Minimal
Mulching	\$100-\$350/acre
Hay and Pasture Management	Minimal
Field Borders(buffer strips)	\$300/acre

Cover crops should be planted regularly after the harvesting of cultivated crops to control erosion. On sloping land, erosion should be controlled with the proper conservation practice such as contour planting. Fertilizer applications should be limited to a rate required by the crop as shown by soil tests. Pesticide use should be limited by identified needs and to the recommended lowest effective rates and frequencies. Irrigation water application rates should be kept within the infiltration rate for the particular soil and slope.

Pastureland is especially susceptible to erosion. The action of dairy cattle stomping over a specific area has the effect of disrupting and compacting the soil surface. Plant growth may be destroyed both above and below ground resulting in bare soil. The potential for erosion and runoff is increased through this process. Pastureland erosion control measures include the following:

1. Keep livestock from congregating in or near streams and on steep slopes. Cost of fencing is approximately \$1 - \$2.00/foot.
2. Provide sediment basins downslope from where livestock congregate (Approximately \$5,000 each).
3. Maintain vegetated buffer strips along streams and lake shores (\$300 /acre).
4. Fill in gullys before they get well started. This will serve to restrict the flow of runoff by removing its most immediate pathway.

Implementation of the first practice may prove unfeasible since it is advantageous to the farmer to locate livestock near a constant supply of water. Steep slopes make good pastureland because they are usually not appropriate for other uses. If this proves to be the case, then sediment basins or vegetated buffer strips should be utilized. These devices will slow the rate of runoff by acting as a trap for sediment and related pollutant loads. In addition, a longer die-off time for coliform bacteria will be provided thus reducing bacterial contamination of the water.

General cost and effectiveness ratings for these measures are presented in Table IV-4

Table IV-4

COST-EFFECTIVENESS OF PASTURELAND EROSION CONTROLS

Measure	Cost	Effectiveness	Cost Effectiveness
Restricting congregations	Moderate	Medium - Low	Poor
Relocating livestock	Moderate to Unreasonable	High	Good to Poor
Sediment basins	Significant	Medium - High	Fair
Buffer strips	Moderate to Unreasonable	Medium	Fair
Filling gullys	Moderate	Medium	Poor

Animals produce a significant amount of wastes. A dairy cow, for example, produces about 3.3 pounds of BOD each day. Waste management practices that will serve to reduce nutrient and bacterial pollution are indicated below. The cost of implementing these measures is minimal.

1. Recycle wastes to the land within the rates usable by crops or assimilable by the soil.
2. Spread wastes on generally flat lands during day periods in the summer and fall when runoff is likely to be minor and vegetative uptake is optimal.
3. Field stack manure on level land which is not in a drainage-way and which is at least 100 feet from the high water mark of any water body.
4. Do not spread manure within 25 feet of a water body.
5. Do not spread manure on frozen ground with more than 3 percent slope.

C. Stormwater and Wastewater Conveyance, Storage, Treatment and Disposal

Collection systems controls are control techniques for the handling of stormflow, runoff and wastewater flow which are intended to reduce or eliminate surcharging of stormwater collection and conveyance facilities. The emphasis is on optimizing the existing collection system. Measures which may be employed include dry-weather cleaning and flushing of sewers, polymer injection and infiltration/inflow control.

1. Catch Basins

Proper use and maintenance of catch basins is a measure which will contribute to improving water quality. The purpose of catch basins is to catch the debris contained in the surface water entering sewers or subdrains. The efficiency of the catch basin is a function of the basin geometry, the flow rate, the influent solids gradation and the accumulated solids held from prior events.

Catch basins are typically cleaned by mechanical means. Either a clamshell type bucket or a vacuum cleaner are the most common methods.

Although various studies have shown that catch basin cleaning is not likely to remove more than six percent of the stormwater BOD load, it is estimated to be capable of effecting up to 32 percent removal of the total solids load. Unmaintained catchbasins can become pollutant sources by resuspension and dissolution of trapped materials. However, even unmaintained catchbasins can become pollutant removers if enough material has collected to cause a filtering action. As a result of this uncertainty an operating policy concerning catchbasins is probably best based on the need to protect from clogging and flooding more than pollution removal unless the basins can be regularly cleaned.

The average cost of catch basin cleaning, based on several studies, is reported to be $10 per catch basin per cleaning. If a cleaning frequency of 2.3 times per year is assumed with 60 catch basins per mile of street and .025 miles of street per acre then the average cost for catch basin cleaning is $34.50 per acre per year. This computed cost will change in proportion to the number of cleanings per year as well as the number of catch basins cleaned in a given community. It is assumed that this represents a total annual cost per acre for mechanical catch basin cleaning.

2. Storm Sewers

The monitoring data has indicated that there is a significant amount of sewage contamination of the storm drains. The sources of this contamination are likely to be numerous. In areas without sanitary sewers, septic tank leaks may be substantial. In areas with sewers, improper connections such as direct sewage connections to storm drains or points of leakage between neighboring sanitary and storm lines may be responsible.

a. Inspection

One practice that can be used for storm sewer collection system control is inspection. Televising is a popular method which may be used for the internal inspection of the storm sewer system. In this manner, restrictions, blockages, cracks, broken joints, improper connections and sources of infiltration/exfiltration may be identified. Costs for televising are indicated in Figure IV-1.

A program of dye studies and enforcement may also aid in identifying problem areas. The City of Worcester's Public Health Department and Public Works Department are currently in the process of identifying and correcting problems as they are found.

b. Restoration

Once problem areas in the sewer system such as cracks, breaks, or collapsed pipe have been located, restoration of the sewer can take place. Methods of rehabilitation range from replacement or grouting to the insertion of sleeves or liners into the sewers. U.S. EPA cost estimates are presented for each of these in Figures IV-2 through IV-4.

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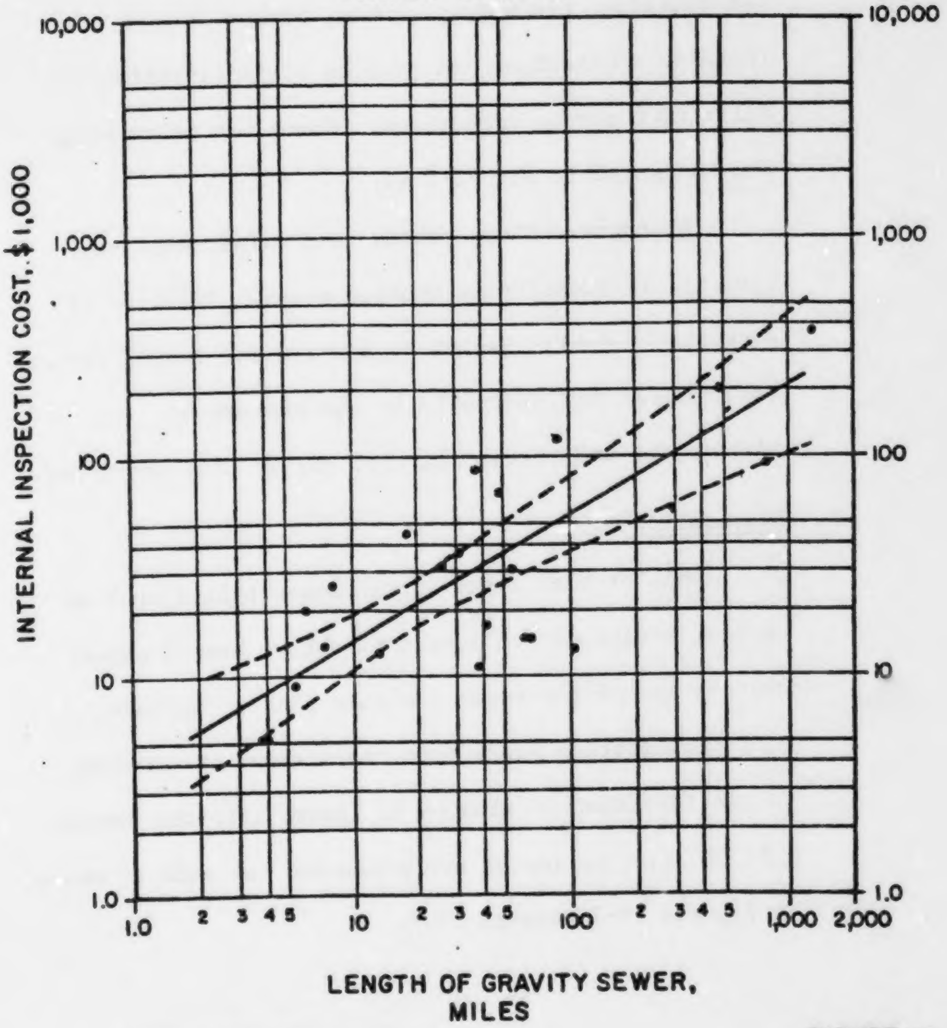
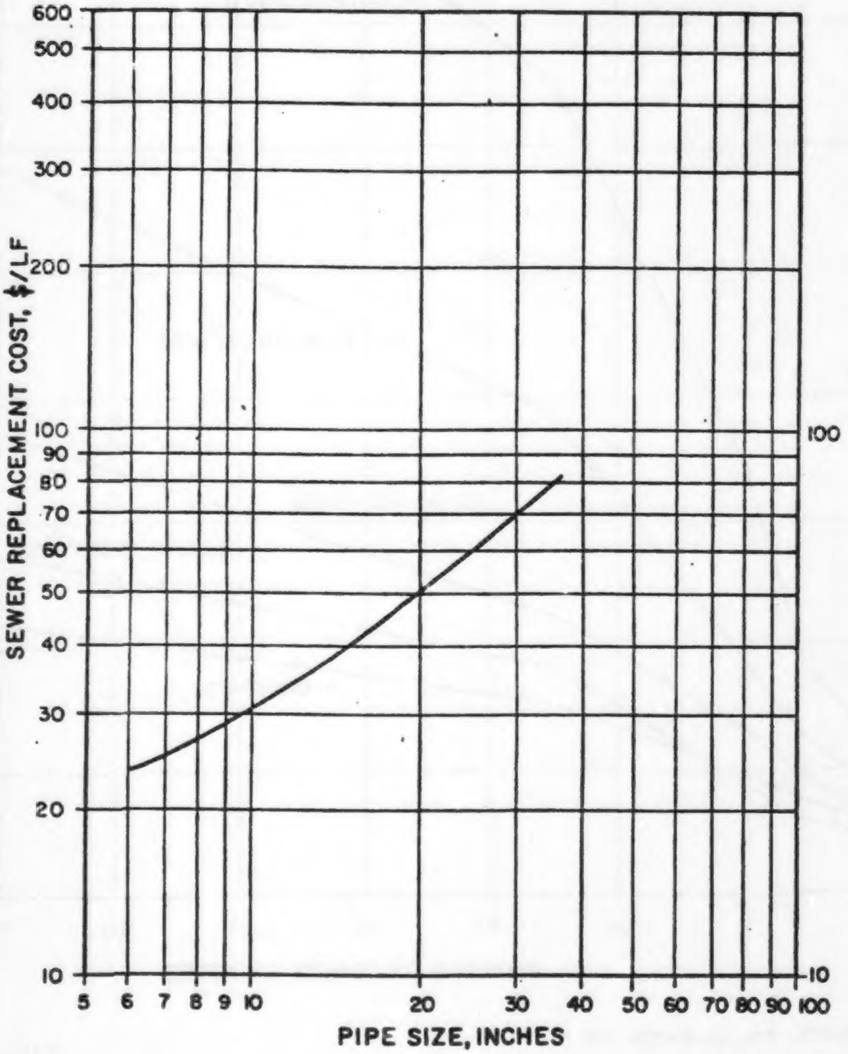
INTERNAL INSPECTION COSTS
VS
SEWER LENGTH



SOURCE: EPA, DECEMBER 1975

FIGURE IV-1

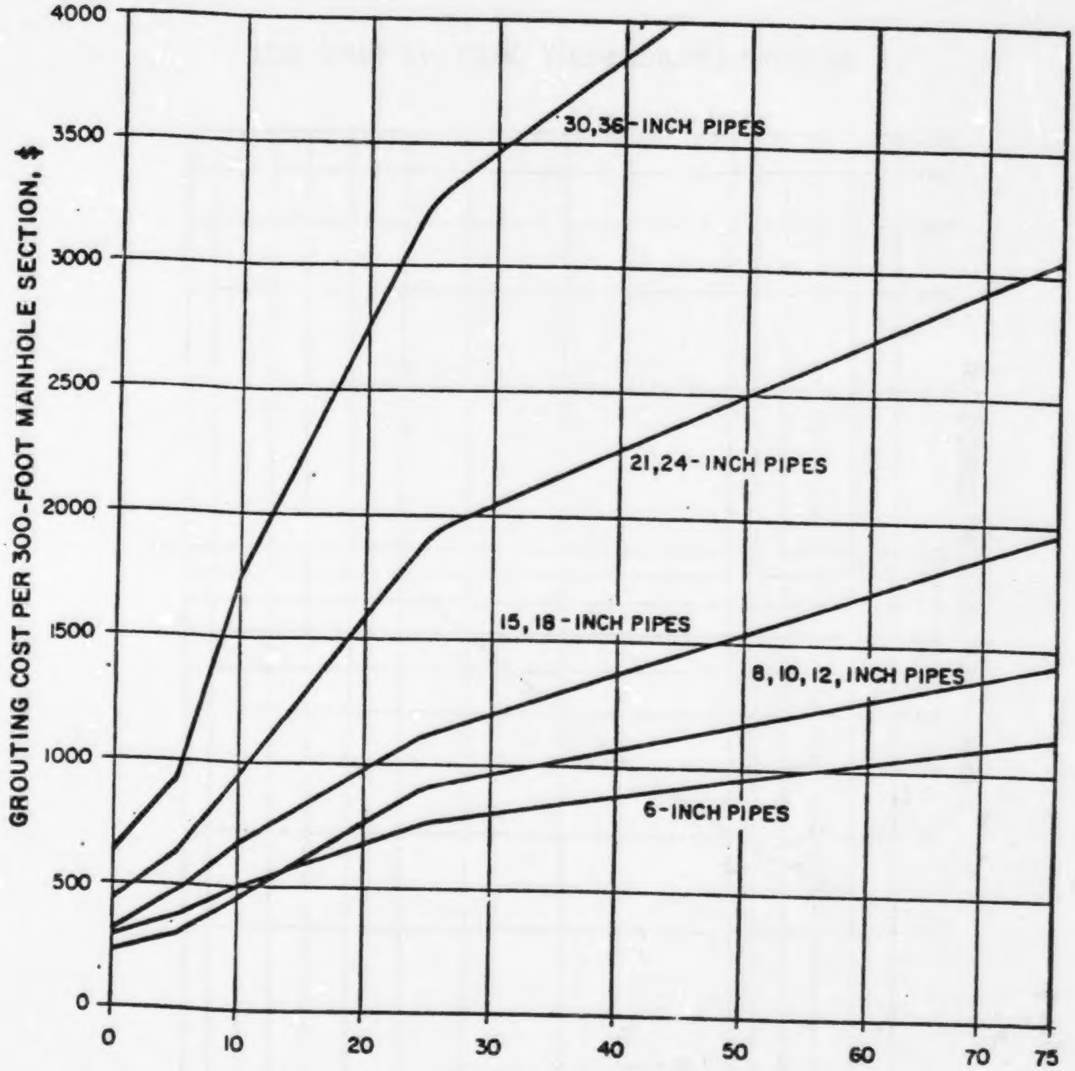
SEWER REPLACEMENT COST VS PIPE SIZE



SOURCE: EPA, DECEMBER 1975.

FIGURE IV-2

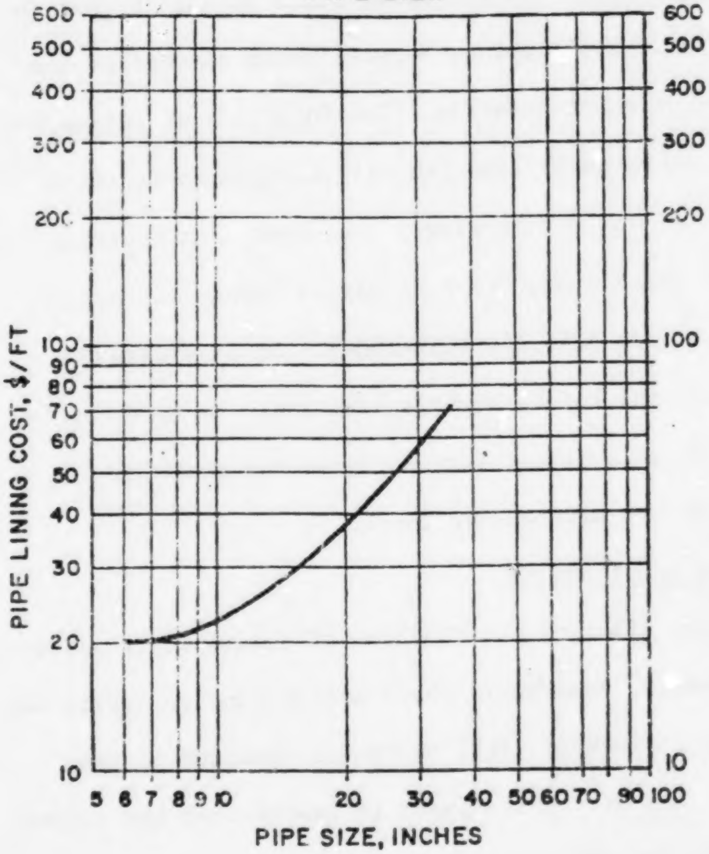
GROUTING COSTS
VS
NUMBER OF PIPE JOINTS GROUTED



SOURCE: EPA, DECEMBER 1975.

FIGURE IV-3

PIPE LINING (POLYETHYLENE) COST
VS
PIPE SIZE



SOURCE: EPA, DECEMBER 1975

FIGURE IV-4

c. Polymer Injection

Polymer injection is an innovative method which is used to temporarily increase pipeline carrying capacity. Polymer gelled slurry injection into sewage has resulted in significant hydraulic friction reductions and, as a result, a temporary increase in the carrying capacity of the line. This is significant in storm water applications because sewer surcharges are usually of short duration. The injection of polymers into a storm sewer line has only limited application because of the comparatively high cost. An installation at the Bachman Creek in Dallas Texas, was estimated to cost $146,000 (ENR=2000). In many cases, modifications to the sewer system could be made for less than this amount without requiring additional operation and maintenance costs.

d. Cleaning and Flushing

The cleaning and flushing of sewers is required periodically, especially where solids tend to settle out, in order to maintain full hydraulic capacity in the sewers. One of the best ways to ensure that the system functions at peak efficiency is to implement a well planned inspection and maintenance program. There are basically three types of cleaning equipment, all of which are very effective when used by skilled operators in the proper situations. General cost estimates for the cleaning of gravity sewers have been prepared by the U.S. EPA (December 1975) and are reproduced on Figure IV-5. Other costs have been prepared by Heaney and Sullivan (1971) which estimate the costs for a ten-acre area in Chicago at $600 per ton of solids removed.

Sewer flushing is another technique that can be used to lengthen the time interval between mechanical cleanings of sewers. Sewer flushing should be used only when treatment facilities are provided and are able to accept the flow, otherwise high organic and solids loadings will be discharged to the receiving stream. Rough cost estimates for sewer flushing installations are presented in Table IV-5.

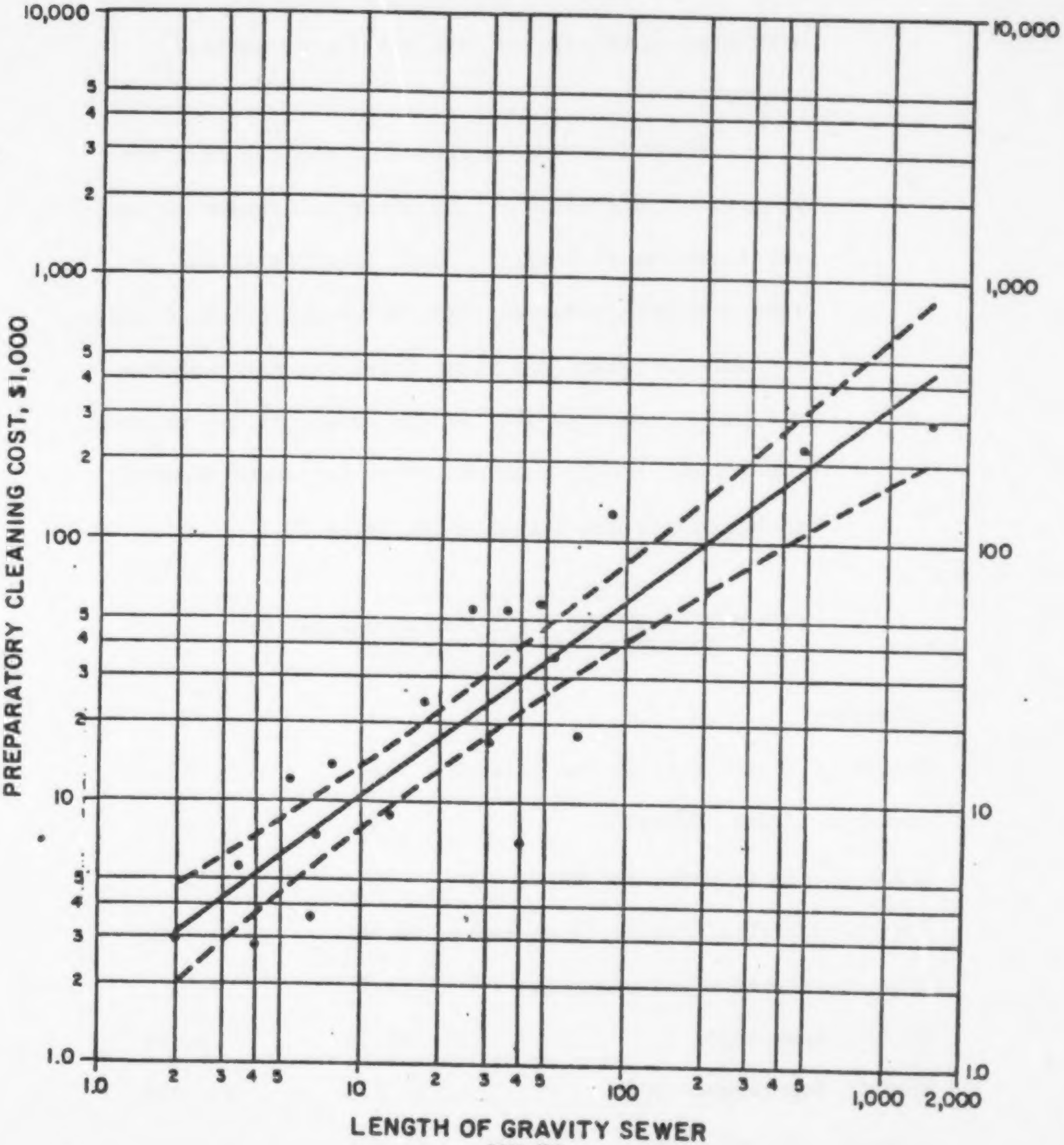
TABLE IV-5
ESTIMATED FLUSHING COSTS FOR DEMONSTRATION PROJECT[a] DETROIT, MICHIGAN

Alternate	1	2
Number of flush stations per lateral	2	4
Area per lateral (acres)	9	9
Daily solids removal (percent)	61	72
Installed cost of fabric flush tanks	$6,380	$12,900
Cost of telemetry and controls	--[b]	--[b]
Monthly power cost	$2.24	$4.69
Monthly maintenance cost	$ 115	$ 229
Capital cost per acre	$ 708	$ 1,430
Monthly maintenance and power cost per acre	$13.00	$26.05

a. ENR = 2000.
b. Not estimated
Note: Acre x 0.405 = ha.

SOURCE: Lager and Smith, 1974

PREPARATORY CLEANING COST
VS
SEWER LENGTH



SOURCE: EPA, DECEMBER 1975

FIGURE IV-5

e. Infiltration/Inflow Control

Infiltration/inflow control will preserve the system's conveyance capacity for its intended purpose (carrying runoff and stormflow) through the exclusion of ground water entrance and the elimination of illegitimate connections. The two basic contributors of infiltration/inflow are: excessive infiltration into sewers from ground water sources and high inflow into sewers through connections from sources other than those that the sewers are intended to serve. Infiltration/inflow control management practices involve:

1) Prevention of infiltration/inflow in new sewers through adequate design; and
2) Elimination of existing problems in old sewers. This involves:

    Replacing defective sections

    Sealing of existing defects

    Building within the existing sewer through the insertion of a liner

Infiltration/inflow control involves an extensive program of cleaning, inspection, and rehabilitation of the sewer, eliminating the need for additional conveyance facilities, and reducing the cost of treatment facilities. The cost of the practices included in such a program have been presented previously.

3. In-line Storage

Since most storm sewers are designed to carry maximum flows far in excess of their normal loads, there is a considerable unused volume within the major conduits which may provide for storage capacity. In-line storage itself is provided by damming, gating or otherwise restricting flow passage. Table IV-6 lists the various regulating devices and their associated costs. Flat sewer grades are necessary in order to be effective. Field, et al. (1976) estimate that in-line storage costs approximately $250-$400/acre.

4. Solid Separation Devices

Solid separation devices include high rate separators such as concentrator/regulators or sedimentation schemes that allow natural sedimentation to occur in an area where the sediment can be removed.

a. Swirl Concentrator

Concentrator/regulators are designed to utilize the forces of gravity and differential inertia between particles and liquids to facilitate separation of solids and liquids in the stormwater flow. The motion of the flow, as determined by the design and construction of the device, allows for the solid/liquid separation at only a fraction of the detention time normally required for sedimentation to occur.

The swirl concentrator/flow regulator is an annular-shaped construction and requires no moving parts. A central circular weir spillway may regulate the flow while the swirling action serves to treat the combined wastewater by the sedimentation induced by the solid/liquid separation.

TABLE IV-6
INSTALLED CONSTRUCTION COSTS AND ANNUAL OPERATION AND MAINTENANCE COSTS OF REGULATIONS[a]

TYPE OF REGULATOR	INSTALLED CONSTRUCTION COST, $	ANNUAL COST PER REGULATOR, $
Broad-crested inflatable fabric dam	4,200-7,200	1,500
Cylinder operated gate	13,000-590,000	1,600-1,800
Cylindrical gate	44,000-166,000	NA[b]
Float operated gate	140,000-260,000	1,500-1,600
Fluidic device	33,000-83,000	NA
High side-spill weir	NA	NA
Horizontal fixed orifice (drop inlets)	1,800-3,600	1,600-2,100
Internal self-priming siphon	NA	800-1,100
Leaping weir	2,800-33,000	1,000-1,200
Manually operated vertical gate	8,500-282,000	1,200-1,500
Motor operated gate	72,000-446,000	NA
Polymer injection	12,900-146,000	NA
Side-spill weir	1,100-25,000	600-700
Spiral flow separator	NA	NA
Stilling pond	NA	NA
Swirl concentrator	124,000	NA
Tipping gate	49,000-418,000	1,500-1,800
Vertical fixed orifice	17,000-37,000	800-1,100
Vortex	NA	NA

a. ENR = 2000.

b. NA = Not available.

SOURCE: Lager and Smith, 1974.

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The swirl primary separator unit is an additional development to the flow regulator which serves to remove a greater portion of suspended solids. The conical shaped device is designed with a depth approximately equal to the diameter which will facilitate higher overflow rates than conventional sedimentation processes. The swirl degritter is a conical shaped hopper below the circular swirl chamber where the solids accumulate prior to discharge.

The concentrate that is formed can be stored in relatively small tanks since the concentrate flow is only a small percent of total flow. Stored concentrate can later be directed to the sanitary sewer for subsequent treatment during low-flow or dry-weather periods, or if capacity is available in the sanitary system, the concentrate may be diverted to it without storage.

The swirl concentrator would serve as an effective control technique for the Belmont Street drain as it receives significant overall sediment loads with very high particulate fractions. It would remove the heavier sediments that are responsible for the sandbar formations in Lake Quinsigamond under the Route 9 bridge. However, it will remove other pollutants only to the degree to which they are associated with solids.

Table IV-7 indicates the approximate capital costs for a minimum level facility at this location designed with a flow of 50 cfs and a swirl diameter of 25 ft.

b. Flow Balance System

Another sedimentation scheme utilizes a flow balance pontoon system developed by Karl Dunkers of Stockholm - Taby, Sweden. This approach directs storm flows through an inexpensive

Table IV-7

Capital Costs for Swirl Concentrator Facility

Description	1981 Dollars
Inlet chamber	45,000
Swirl/solids concentrator (25 ft.dia.)	150,000
Swirl degritter w/out solids removal	50,000
Piping/outlet structure	50,000
Fencing/landscaping/access road	50,000
	345,000
15% contingency	52,000
	397,000
15% engineering, legal & admin.	60,000
TOTAL	$457,000

system of baffles to enable sedimentation to occur in a controlled area. There appears to be sufficient space within the lake behind Ramshorn Island for this system. The island allows separation between the lake's narrow boating area and the area required by the pontoon system. The pontoon system would require access from the west side of the lake for management of the system and periodic dredging of the captured solids. However, the concept is to store storm flows in the baffle system and pump the stored liquid to the sanitary sewer system. The costs of pumping to raise the water to the sanitary line on Lake Street would be excessive. Therefore this system can not be recommended.

5. Runoff Diversion

In situations such as in the Lake Quinsigamond watershed where there is no clearly identified source of a key parameter (dissolved phosphorous), then a volumetric reduction of storm flows may be necessary if loadings are to be significantly reduced. As dissolved phosphorous loadings in the basin follow flow, the amount of dissolved phosphorous reduction that can be achieved is roughly the same as the volume reduction that can be achieved. The reduction can be effectuated by various means one of which is by diversion around the Lake to a point downstream on the Blackstone or Quinsigamond Rivers.

Diversion of runoff by collecting and pumping stormwater to the Blackstone or Quinsigamond Rivers would be difficult to achieve due to the long narrow shape of the lake. Major storm drains would have to be diverted through relatively fairly long intercepting storm drains to bypass the lake. The construction cost of the intercepting drains and pumping facilities is likely to be prohibitive.

6. Septic Systems

The indirect discharge of pollutants from improperly located, malfunctioning or crowded septic systems can have detrimental effects on any waterbody. The addition of excessive nutrients, particularly nitrogen and phosphorus, as well as solids and organics impairs water quality while pathogenic organisms can pose a potential health hazard.

If a septic system is designed based on accurate soil information and is properly installed, used and maintained, it can serve its owner over a long period of time. Unfortunately, many septic systems fail because of poor design, improper installation, and the stresses placed on them by misuse and improper maintenance.

Improper maintenance is probably the largest cause of septic system failures. In order to maintain a well functioning septic system, an understanding of the system, its components and operation is essential. Septic systems consist of a septic tank and drain field or leaching area. Household sewage which is a combination of wastewater from several sources including sinks, toilets, showers, washing machines, garbage grinders and dishwashers flows by gravity into the septic tank. During the detention period within the tank, particulate solids in the sewage either settle to the bottom forming a layer of sludge or float to the surface creating a scum layer. This sludge and scum are retained in the septic tank and the remaining conditioned wastewater is allowed to flow into the leaching area. The leaching area consists of either a perforated concrete chamber or a series of perforated pipes leading to a stone-filled area. The water is permitted to trickle through this area ultimately reaching the the soil. The soil, in turn, performs many functions such as filtering out particles, absorbing viruses, straining out bacteria and renovating wastes into reusable nutrients, part of which are consumed by organisms contained within the soil itself. The soil, however, has a limited capacity in this respect and some pollutants will unavoidably enter into the ground and surface waters. In order to minimize this impact, care should be taken to prevent septic system failure which would introduce even more pollutants.

Some of the sludge and scum that are retained within the septic tank are reduced to liquid by bacteria but the rest of the material must be pumped out at regular intervals. Failure to do so may result in sludge and scum entering the leaching field where these substances will clog the soil. The septic system may then cease to function properly at which point it may even be necessary to build a new leaching area. It is generally recommended that septic tanks be pumped out every 2 to 5 years. The estimated cost for a new system is $1,000 to $3,500 and it can cost this much or more to repair a system while a routine pump-out runs between $50 to $100.

Several factors may contribute to septic system malfunctions. The homeowner should be aware of the following points:

- The microbes in the septic tank must be treated with care. Small amounts of soaps, detergents, bleaches, and the like will not harm the treatment process taking place in septic tanks; but, an overdose of any of these can be fatal to the needed biological activity.
- Cigarette butts, filters, sanitary napkins, disposable diapers, hair, paper towels, and napkins cannot be properly digested in the septic tank and simply add to the sludge volume. These items should be disposed of in the trash bin.
- Grease and fat float to the top as scum and are usually not fully digested. When combined with detergents or when emulsified, grease passes through the tank into the drainfield, thus, clogging the soil.
- Systems may be too small for an intended use. The soil in the leaching field may be insufficient or unsuitable to absorb the volume of wastes being introduced.
- Careless workmanship can be a problem. For a variety of reasons, systems may not have been installed according to specifications.
- Systems may be improperly sited, too close to adjacent systems, or designed and installed too near the water table. In this last case, wastes are added directly to the groundwater without adequate purification in the soil.
- A septic tank may fill with accumulated sludge, overflow into the leaching bed and clog the soil in the leach field.
- The infiltration capacity of any soil will decline with time. Unless this loss in capacity is accounted for in the field design, the system will eventually malfunction.
- Pipes may be crushed by heavy objects such as trucks.

Although it is not always obvious that a system is about to fail, certain warning signs within the leaching area may be apparent.

Ponded water, sewage odors, nitrogen uptake by grass resulting in bright green patches, areas of melted snow in the winter and slow-running drains and toilets are all symptoms.

To help protect a septic system against premature failure, the homeowner should follow these simple procedures:

1. Pump the septic tank at least once every three years or have it inspected for signs that it may fail. Do not wait until the symptoms of failure show up.

2. Minimize water use in the home. Excess water will decrease the effectiveness of the septic tank and lead to flooding of the leaching area. Never empty basement sumps or other sources of clear water into the septic system. Use water saving plumbing fixtures where possible (faucet aerators, low-flow shower heads, low-flow flush toilets, flush tank dams, etc.) and run dishwashers and washing machines only with full loads. Fix all leaky faucets and toilets promptly.

3. Certain materials interfere with effective operation of septic systems; although small amounts of garbage material may be acceptable, avoid the use of a garbage disposal. Don't dispose of the following substances in the septic system (recycle them by composting or put them in the trash):

    - Coarse organic matter such as vegetable trimmings, ground garbage, sanitary napkins, eggshells, cigarette filters and coffee grounds clog the septic tank with sludge and promote frequent septic tank pumping.

    - Automotive oil should never be put into the septic system. Cooking oil and bacon grease, etc., may pass through the septic tank and clog the leaching area causing the system to back up.

    - Pesticides, disinfectants, acids, medicines, paint, paint thinner, etc., will kill the bacteria which decompose organic matter in the septic tank, thereby causing increased sludge accumulation. As a result, more frequent pump-outs will be required to keep the system operating properly.

4. Insist on proper location and construction of any new leaching area. Improper location and construction will usually result in problems and failure of the system.
5. Keep heavy vehicles off of the leaching area; their weight could lead to crushed pipes and expensive repairs, as well as loss of soil infiltration capacity (due to soil compaction).
6. Don't plant deep rooted trees or bushes over the leaching area; their roots may clog or dislocate pipes.

A mandatory septic system maintenance program requiring periodic inspection and cleaning is one method of alleviating septic system problems. A program of thorough inspection conducted by trained inspectors would reveal any malfunctions that were present. Septic systems could be evaluated as to their general condition and the need for sludge pumping or grease removal. Structural defects and signs of current or recent failure could be pinpointed. In this manner, septic systems requiring pumping would be pumped and defective systems replaced or repaired as necessary. In critical areas such as along lake shores inspection could be conducted on a more frequent basis.

The cost for staffing and operating such a program would include salaries for the inspectors, septage pump operator/driver and support staff plus vehicle operation, maintenance and insurance costs. For a town with 3,000 existing septic systems, an annual expenditure of $80,000 to $100,000 (1977 dollars) would be required. If the town employs the services of an existing private pumper, then a savings may be realized in lower pumping prices.

Septic systems, if properly functioning and maintained, do serve an important role in supplying needed nutrients and recharge water to an area. However, alternatives such as sewering may be necessary if untreated pollutants enter the groundwater or surface waterbodies.

7. Disinfection

The intention of disinfection is to destroy pathogenic organisms and to prevent the spread of waterborne disease. Many pathogenic bacteria, along with other microorganisms, are destroyed or removed in different amounts by the following treatment process:

Use of physical agents -

- Ultraviolet light
- Heat

Use of chemical agents -

- Chlorine
- Sodium or Calcium Hypochlorite
- Ozone
- Bromine

The ideal disinfectant should have a potent germicidal action, low toxicity to higher life, low affinity for extraneous matter and work at a rapid rate with a low cost.

The factors which influence disinfection include:

- Contact time
- Concentration and type of disinfectant
- Temperature
- Number, type and nature of organisms
- Nature of suspended solids
- pH value of substrate

Following is a discussion of the different methods of disinfection.

a. Heat

Heat works effectively against microorganisms by destroying their cell protein. A temperature of 100°C will kill most living organisms. However, some resistant spores require even greater temperatures. A continuous-flow water pasteurizer was developed to treat farm ponds, cisterns and other similar domestic water supply sources. This unit treats 250 gallons over a period of 12 hours. Water is pasteurized at 161°C for 15 seconds by a heat exchanger that recovers all but 10°F of the heat required for treatment. This method is very effective even with very high bacterial concentrations. The total cost based on household scale treatment was estimated at $1 per 1,000 gallons (1971 dollars). It is a very reliable and simple system but is expensive for the disinfection of large quantities of water and lacks residual disinfection action. The addition of considerable amounts of warmed water would have a detrimental impact on the aquatic environment. The capacity for dissolved oxygen concentration would decrease, the cold-water fishery would be disrupted, and it would promote the growth of select blue-green algae which sometimes emit toxic materials and are not a very desirable aquatic animal food.

b. Ultraviolet Light

The ultraviolet light radiating from the sun has the ability to kill selected unprotected microorganisms in surface waters. In order to be effective, the electromagnetic waves of ultraviolet irradiation must actually strike the organism.

This type of disinfection requires quartz mercury-vapor arc lamps which emit germicidal ultraviolet radiation. Since ultraviolet light has a very low penetrating power, water must be passed under the lights in a very shallow layer (up to about 3 inches thick) so that all of it is exposed to the ultraviolet rays.

This method has the advantage of not altering the physical or chemical character of the water and also constituents of the water, such as ammonia, exert no effect on disinfecting ability. Relatively short contact periods are required and overdosing produces no detrimental effects.

However, this system requires a great deal of energy and expensive equipment as well as frequent maintenance to ensure stable energy application and a uniform density throughout the effective radiation area. Ultraviolet light does not provide residual disinfection action and water must be preconditioned because radiation is absorbed by many constituents which may act to shield organisms from the ultraviolet light.

Under a US EPA grant a demonstration project was conducted by the Vermont State Department of Health to investigate and compare chlorine, ozone and ultraviolet radiation as practical methods for disinfecting small water supplies. Ultraviolet light proved to have a much higher cost than chlorine. The capital cost of the ultraviolet method for a 20,000 Gallons per day system was $1.995 with annual operating and maintenance costs at $458 while the cost of a hypochlorinator was $550 with an expenditure of $141/yr. for chlorine.

c. Chlorine

Chlorine is the most common disinfectant at the present time. Chlorine compounds are both inexpensive and very effective antimicrobial agents. Their effectiveness is dependent on temperature, pH and the chemical state of the chlorine. In the presence of ammonia, chlorine will be converted to chloramine which has a much lower disinfecting power. These compounds are relatively stable and extremely toxic to fish and other aquatic life. Chlorine also combines with organic compounds and reacts with reducing substances such as ferrous iron and hydrogen sulfide. Both of these processes form products with no disinfecting capability. The formation of chlorinated hydrocarbons may even be toxic or carcenogenic.

It is the free residual chlorine that is the most effective disinfectant. It is imperative, therefore, that sufficient contact time is allowed, generally 20 to 30 minutes to bring about satisfactory disinfection. For this reason high dosages of chlorine may be necessary.

Liquified chlorine gas is available in 100-to-150-lb cylindrical containers, 1-ton containers and 16-to 55-ton railroad tank cars. It is dispensed by metering the gas directly into the water or by first preparing a concentrated aqueous solution. Figures for the various forms of chlorine are indicated in Table IV-8.

Although chlorine gas is inexpensive, it is extremely hazzardous. It is available in a limited range of container sizes which must be moved to the point of use. For this reason, it is

TABLE IV-8
CHLORINE COST FIGURES
(Based on 1976 costs)

Agent	Approximate Cost
Chlorine in tank cars	\$0.05/lb. Cl_2
Chlorine in 1-ton cylinders	0.11/lb. Cl_2
Chlorine in 150 lb. bottles	0.24/lb. Cl_2
Sodium hypochlorite in 55 gal. drums (14% avail. Cl_2)	0.58/lb. Cl_2
Calcium hypochlorite in 50 lb. drums (65% avail. Cl_2)	1.55/lb. Cl_2

Source: Culp, Wesner, Culp; 1978

undesirable for disinfection at locations that are not staffed continuously or that are accessible to the public.

d. Hypochlorite

Two other forms of chlorine that are available include calcium hypochlorite and sodium hypochlorite. These compounds are safer to handle than chlorine gas but are more expensive than ton-containers of liquid-gas chlorine.Table IV-9 presents the costs associated with chlorine gas and hypochlorite disinfection.

Calcium hypochlorite has at least 70 percent available chlorine and is very soluble in water. It is available in granular and powdered form and can be mixed with water to a desired strength. Sodium hypochlorite is also a readily soluble compound which is available in liquid form at concentrations between 3 and 15 percent available chlorine.

Both sodium and calcium hypochlorite give the same dissolved chlorine species as molecular chlorine with the formation of chloramines. These agents do present some handling and storage problems. Calcium hypochlorite, if improperly stored, may cause spontaneous fires and sodium hypochlorite flakes deteriorate rapidly in the presence of moisture. All hypochlorite solutions are subject to deterioration with time, heat and exposure to sunlight. For this reason it is necessary to adjust the hypochlorite feed rate at the time of application to maintain the desired concentration.

e. Bromine

Bromine is a highly corrosive liquid and must be handled with great care. Corrosive resistant equipment is necessary for its safe utilization. In addition, bromine has very irritating fumes and

TABLE IV-9

Cost Data for Chlorine Gas and Hypochlorite Disinfection

Location	Purpose	Agent	Capital Cost $	Operating Cost, $/yr.	Cost/lb. Available Chlorine, $
Akron, OH	Combined sewer overflow disinfection	Sodium Hypochlorite Purchased	441,500	23,300	0.152 - 0.264
Cambridge & Somerville, MA	Combined sewer overflow disinfection	Sodium Hypochlorite Purchased	---	---	0.385
		On-site generation	---	---	0.200
Saginaw, MI	Combined sewer overflow disinfection at use rate of 42,000 lb/yr of chlorine	Chlorine gas	161,000	2,300	0.35
		Sodium Hypochlorite Purchased	19,550	6,325 -11,500	0.18 - 0.31
		On-site generation	94,450-161,000	4,715 - 5,175	0.28 - 0.40
South Essex Sewerage District, MA	Sewage treatment plant effluent disinfection at use rate of 24,000 lb/day of chlorine	Chlorine gas	872,460	233,100	0.035
		Sodium Hypochlorite Purchased	421,800	364,080	0.046
		On-Site Generation Sea water	1,665,000	160,950	0.035
		Brine	1,665,000	303,030	0.051
New Orleans, LA	Storm sewer discharge disinfection	Sodium Hypochlorite On-site generation	581,700	290,000	0.120

SOURCE: Lager and Smith, 1974

will cause severe burns on contact with the skin.

Bromine will react with any ammonia that is present in water to form bromamines which are somewhat unstable, breaking down into harmless elements in less than an hour. Due to this fact and because reducing agents exert a rapid demand action, a portion of bromine added to the water is lost almost immediately and will contribute nothing to disinfection. In one experimental situation, it was found that in order to achieve a 99.995% kill of coliform bacteria, 45 mg/l of bromine was required as opposed to only 8 mg/l of chlorine. The unstable nature of the bromamines, however, has a positive effect in that it does not present any fish toxicity problems as do the chloramines. Bromanimes are good disinfectants approaching free chlorine and free bromine in this respect.

Bromine has a higher cost than chlorine, in general, about 3 times the market price of chlorine. It is only slightly soluble in water and has not been used very extensively in the purification of water due to its considerable cost and difficulty in handling. The availability of bromine compounds is limited and there has been insufficient field experience to evaluate bromine as a disinfection process.

f. Ozone

Ozone has a strong oxidizing ability and is capable of rapidly destroying bacteria and viruses. It is prepared by passing dry air through a high-tension electric current. It is very unstable and cannot be stored economically. For this reason, it is usually applied to the water immediately after generation. Ozone generators range in capacity from 0.5 to 63 lb/24 hours. The cost of operating such a device is directly related to electrical power costs and the concentration of ozone produced. It may require 4 to 16 times as much energy to produce ozone. The power to produce one pound of ozone from air ranges between 10 to 12 kilowatt hours. If pure oxygen is used, the power required will be reduced to 5 to 6 kilowatt hours per pound of ozone. A minimum of .5 mg/1 will sterilize clear water; however, as turbidity and suspended solids increase, the required dosage also increases.

Capital costs will vary according to the system employed and its capacity. For a skid mounted system with a capacity under 12 lb/day, the cost would be approximately $1700 per pound of ozone produced. For a system with a capacity over 1000 lb/day, the cost would be between $200 to $300 per pound of ozone produced.

Ozone is a most effective sterilizing agent whose disinfectant action is effective over a wide pH and temperature range. Bactericidal and sporicidal action is very rapid with only short contact periods required. Waters that contain high organic and algal content, however, require thorough pretreatment to satisfy the ozone demand. The ozone-air mixture that is produced is only slightly soluble in water and the procedure is complicated by high temperatures and humidity. It is also less flexible than chlorine for adjustments to flow rate and water quality variations. There is no lasting residual disinfectant action and the electric energy as well as capital and operating costs are high.

D. Landfill Alternatives

The disposal of solid waste in an environmentally sound and safe way can be difficult and expensive. Traditionally much of the solid waste that has been generated has been disposed of in landfills or by incineration.

1. Sanitary Landfills

Disposal in a sanitary landfill means that refuse is deposited on a portion of the fill, spread out, compacted and then a cover material is applied. Compaction serves to provide both a stable base and resistance to the movement of water through the fill. To limit infiltration from rainwater and surface water an impermeable cover must be applied within one month after refuse has been deposited. The estimated costs of operating a landfill are presented in Table IV-10.

Once a landfill has been filled to capacity and is closed, it should be sealed with an impervious material to prevent leachate generation which has the potential to continue for many years. Synthetic materials such as Hypolon and Polyvinyl Chloride may be used for this purpose. Additional techniques that are available include the application of a mixture of natural soil and clay or hot sprayed asphalt. Synthetic material priced at $4.50/sq.yd. would cost over $20,000/acre while hot sprayed asphalt would cost approximately $8,500/acre. A natural soil/clay mixture would cost considerably less if on-site soil were utilized.

A final cover consisting of two feet of compacted and seeded earth should follow sealing. Cover should be graded at a minimum of 2% slope to promote runoff and eliminate water ponding on the surface.

Estimates of the costs required for the closing of a landfill range from $15,000 to $160,000 depending on size, availability of closing materials and the potential for pollution from the landfill.

To open a new landfill the initial investment would include the purchasing of land, equipment, and facilities. Costs for planning, developing and engineering must also be taken into account. Table IV-11 indicates the approximate costs associated with the development of a 20-acre site. Further costs may be incurred if there is controversy over a proposed location. Litigation, hearings and associated delays will add to the overall cost.

2. Regional Sanitary Landfill

One option to individual landfills is a regional sanitary landfill which

TABLE IV-10

SUMMARY OF LANDFILL OPERATION COSTS

AMOUNT OF WASTE(TONS)	PERIOD OF TIME OVER WHICH WASTE IS DEPOSITED (DAYS)	COST PER TON
18	14	$ 8.00
33	15	5.40
72	16	4.00
100	17	4.80
250	18	2.30
500	19	1.80

TABLE IV-11

ESTIMATED LANDFILL DEVELOPMENT COSTS*
(FOR A 20-ACRE SITE)

Cost of Land	$40,000	to	$ 80,000
Planning and Design			$ 12,000
Geologic Study			$ 10,000
Site Development (fencing, lanscaping,drainage, access roads, clearing, filling, etc.)			$ 25,000
Facilities (shelter, weight scales, utilities, fire protection, etc.)			$ 50,000
Equipment (crawler/loader)			$ 75,000
TOTAL	$ 212,000	-	$ 252,000

* 1978 DOLLARS

will serve a district or particular group of towns. Under this concept the landfill would be operated either through the formation of a district or by a "host town". The formation of a district gives it the authority to plan, take land by eminent domain, issue bonds, and contract for waste disposal. One disadvantage would be the loss of local control over the operation by individual communities.

The second concept involves the selection of one community to act as a "host town". This town will operate the facility and contract with the other member communities for its use. Under this plan an individual community would not have the same power and authority as a district to finance a multi-town facility and power over the operation and finances of the facility would be minimal for the contracting communities.

There are several advantages inherent in such a regional system . The disposal of solid waste for several communities can be effectively coordinated. A greater deal of flexibility will be allowed regarding the location of disposal sites since there is a wider land area from which to select a suitable site. This is an important consideration as existing landfills reach their capacity and towns must find a new and acceptable location. This process is complicated due to increased land development and stringent site selection requirements. A regional facility will serve to reduce both the land requirements and expense associated with individual town landfills. The duplication of items such as fences, shelters, scales, roads, etc.would be eliminated. Table IV-10 illustrates considerable economics of scale with increasing facility size and tonnage disposed. Fixed cost items such as equipment, utilities, labor, administration, access roads,etc. do not increase in proportion to capacity and therefore decline on a per ton basis with increasing capacity.

This system will also eliminate duplication in the use of consultants to perform initial surveys. Air and water pollution abatement activities can be more effectively controlled and coordinated.

Multi-townfacilities may require the use of transfer stations for member towns which are distant from the disposal site. Table IV-12 presents the operating and capital costs for such stations. The cost of transporting compacted refuse to the disposal site is roughly estimated at $.08 per ton mile with an additional $.56 per ton for unloading.

TABLE IV-12 *

COSTS FOR TRANSFER STATIONS

	Capacity (tons/day)	Capital Cost ($)	Operating Cost ($/ton)
Unmanned Station	1.1	14,500	9.42
	4.3	19,800	3.70
	7.2	27,900	3.00
	12.0	36,000	2.25
Manned Station	25	88,000	4.90
	50	120,000	3.10
	100	180,000	2.60
	500	340,000	1.05
	1000	470,000	0.75

(*Arthur D.Little,Co.," Opportunities for Regional Solid Waste Management", April 1975.)

Regional landfill systems offer considerable economic and environmental benefits by reducing unit costs while providing a higher quality operation meeting environmental standards. However, there is often difficulty among the towns over reaching an agreement on location of the disposal site. The location of a facility in one town which will receive the waste from several other communities usually receives strong local opposition. Public education programs and economic incentives may serve to dispel misconceptions and opposition.

3. Resource Recovery Plant

Improperly operated and sited landfills can post significant water quality problems. If water is allowed to percolate through the refuse, it will leach out contaminating the groundwater. The leachate that is formed may be toxic and can contain sulfates, chloride , calcium, phosphate, iron, lead, manganese,zinc sodium, chromium and arsenic.

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One alternative to this method of waste disposal is a resource recovery plant. This type of facility processes wastes to recover both energy and materials. Energy recovery is accomplished either by the production of liquid, solid or gas fuel or by the combustion of refuse to generate steam. Materials that may be recovered include primarily aluminum, iron and glass.

A resource recovery plant would save millions of gallons of oil annually and permanent jobs would be created to operate the facility. A properly designed plant would not produce odors and stack emissions could be almost 100% pure. If all activities were totally enclosed noise would be at a level well below industrial standards. The volume of truck traffic to the proposed plant can be minimized by the use of transfer stations and trailers in addition to regulation by local ordinances, contract provisions and strict supervision.

One prerequisite for the implementation of a resource recovery plant is that the area served be large enough to supply between 1,000 and 3,000 tons of refuse a day. Since the City of Worcester alone at the present time generates approximately 650 tons of domestic and commercial solid waste per day, this requirement should be easily fulfilled.

The capital cost for a resource recovery plant is in the range of $20 million. One proposal for a facility in the Worcester area estimated the annual operating charges to be between $3 and $4 million. However, the sale of recovered materials would provide income which would offset some of the operating expenses.

A privately financed, constructed and operated facility would serve to stabilize the local tax rate by providing a long range efficient and economical method of solid waste disposal.

4. Recycling

Recycling is another alternative to deal with the solid waste problem.

Recycling conserves rapidly dwindling natural resources as well as eliminating environmental deterioration and pollution. There are markets in Massachusetts for the recycling of paper,metals and glass. However, recycling on a large scale is not as economically profitable as other solid waste disposal methods. Federal subsidies in addition to State and Federal tax incentives would be advantageous in promoting this method.

E. In-Lake Restoration Techniques

In order to be effective, a water quality management plan must seek to identify and eliminate present or potential sources of water quality degradation. Reliance solely on in-lake restoration techniques such as dredging, harvesting or phosphorus inactivation will merely ameliorate the symptoms of pollution without attacking its cause(s) and will accomplish little in the way of a long term solution for lake restoration. However, once pollutant sources are under control and pollutant loadings are reduced to allow the desired water quality to be maintained, in-lake restoration techniques can be very effective. They are particularly useful when recovery from a degraded condition may be slow or may not take place at all even after implementation of a watershed management program and also when the accumulated material in the lake constitutes a significant source of pollution.

An aquatic plant problem exists in Flint Pond and in the shallow areas in the northern section of Lake Quinsigamond above Lincoln Street. Dense growths of rooted aquatic plants restrict recreational activities and limit the fishery potential. Profuse vegetation utilizes a great deal of water space permitting fish to escape from their predators to such an extent that overpopulation and stunting results. Dense surficial growths and the constant downward movement of dead organic material create an organic muck which will build up on the lake bottom. Coupled with siltation, water depths may be reduced allowing more sunlight to reach the bottom thus accelerating the growth of rooted aquatic vegetation. This nutrient rich organic muck may constitute a significant source of dissolved phosphorus and cause dissolved oxygen depletion.

There are several corrective measures which can be considered for the abatement of nuisance aquatic weed growth including dredging, weed harvesting, herbicide application and lake level drawdown.

1. Herbicide Application

Herbicides are chemicals which are applied to the aquatic environment for the control of nuisance aquatic vegetation. The method of application and the dosage required is dependent on the species to be controlled. Herbicides may be spread on the water or applied below the surface, sprayed on the plants or applied to the exposed bottom soil. Regular retreatment is required since lasting control is not provided. In most cases, herbicides leave persistent residues harmful to non-target species such as fish and fish food organisms. Since plants are not removed, they will contribute to the organic detritus on the pond bottom releasing more nutrients and depleting oxygen. The cost of these chemicals can be considerable for very temporary relief. Because of the various environmental problems related to large scale herbicide treatment, this alternative is not considered to be a viable one.

2. Weed Harvesting

Weed harvesting provides immediate relief from nuisance plant growth and will greatly improve the recreational potential of a waterbody. This method involves a phased operation of cutting, harvesting, lake to shore transport,and ultimate disposal. Unlike herbicide treatment, this procedure is target specific. The regrowth of plants is slowed by multiple cuts and in subsequent years growth is inhibited.

The harvesting of weeds does remove a certain type of animal habitat. Thick growths, however, do not provide for optimal utilization of the habitat. Once weeds are removed a new area may be opened up to fish that otherwise found it too dense to travel.

Most aquatic weeds are composed primarily of water with a small portion being solid material. Once harvested and dried, the disposal material will amount to approximately 10% of the original weight. Since these weeds are rich in nutrients, they may be used for several purposes including mulch, compost, and animal feed. It generally takes a few weeks for the weeds to decay and a fishy odor may be emitted early in the decomposition,but this is only a temporary condition.

Cost estimates for this procedure range in price from $70- $100 per acre (1980 dollars) which includes labor equipment, depreciation and disposal.

Harvesting does not remove the hydrosoil or muck buildup which is the nutrient-rich foundation of the weed mat and will probably not affect any large scale nutrient balances. Therefore, this procedure may not be a very effective long term control alternative for Flint Pond and the northern section of Lake Quinsigamond., if only conducted on a one-time or short-term basis.

3. Dredging

Dredging is the process by which sediments are removed from the lake bottom. This method eliminates the very platform on which weeds grow and limits regrowth by physical deepening and nutrient removal. Lake deepening will restore any impaired recreational activities although its effect on controlling rooted aquatic plants is not well documented. This process may also serve to remove sediments contaminated with toxic materials.

Sediment removal is usually accomplished with a hydraulic dredge. Lake level drawdown is another technique that is used to expose sediment for removal by conventional earth-moving equipment. Sediment cores from several depths are necessary to determine the nutrient release potential which will indicate how much material must be removed.

Dredging is especially appropriate in ponds and lakes like Flint Pond which are excessively shallow and plagued by rooted aquatic plants. The rate of transport of sediment and nutrients from external sources will determine the duration over which the effects of dredging may be maintained. A successful watershed management plan will be very beneficial in this respect.

Dredged material will contain vast amounts of water in addition to organic and inorganic compounds. A disposal site for this material must be carefully selected to prevent the reintroduction of nutrients and chemicals to other water resources. Terrestrial decomposition may result in an earthy odor at the site and the pH of the soil as well as terrestrial plants and wildlife may be affected by potentially toxic and non-toxic materials. If the dredged material is transported long distances to a disposal site, this will add considerably to the cost. In some instances, productive uses may be made of the dredged material which will serve to offset some of the costs. There may be a market for the fibrous peaty material or it may be used as a cover material in landfills or on agricultural land.

Dredging may resuspend fine particles and the nutrients associated with them creating turbidity and an increase in algal growth. Toxic substances may be released to the water column. Benthic organisms which are important to the fish community may be destroyed. However, this effect is only temporary and fishing may be enhanced after the reestablishment of these organisms.

The price of dredging will vary depending on the amount of material to be dredged and the location of the disposal site. Costs can range from as little as $0.76 to a high of $12 per cubic yard. Estimations for the northeast region of the United States indicate $4.30 per cubic yard as the average price.

4. Lake Level Drawdown

Lake level drawdown is another technique used to control nuisance rooted aquatic plants. In addition, it can be used to consolidate flocculent sediments by dewatering; dredging may be accomplished by using conventional earth moving equipment and sediment covers can be more easily applied.

Lake level drawdown works to control rooted aquatics by exposing them to extreme cold or heat for a period of 1 to 2 months. This exposure will prove lethal to susceptible species. Since this procedure is species selective it is important to identify the organisms present. The presence of resistant species will result in their rapid propagation upon lake refilling. If the lake sediments are not sufficiently dewatered, reproductive structures may remain allowing otherwise susceptible plants to survive.

Other beneficial effects may be derived from lake level drawdown in addition to the control of nuisance rooted vegetation. Fishing is enhanced by removal of vegetation and by concentrating small fish into a lesser volume of water where predation by gamefish is more intense. Turbidity and the concentration of nutrients which contribute to algal growth may be reduced.

Several negative effects associated with this technique have been made apparent. Blooms of nuisance algae may occur caused by either a mineralization of nutrients in organic-rich sediments or to a lack of competition by rooted aquatics. Organisms living within the lake sediments may be destroyed adversely affecting the fish which feed on them. Hardening of the exposed mud may also delay the reestablishment of these organisms. Chemical changes may occur in the exposed muds causing an increase in the release of chemicals to the water upon reflooding. Terrestial plants may invade the exposed mud flats providing additional nutrients to the aquatic ecosystem upon reflooding. Failure of the lake to refill may be caused by insufficient watershed drainage area, drought, or delay in closing the dam until too late in the season. These negative effects can be minimized by good management practices and an awareness of their impacts.

The cost for implementing this procedure would be minimal especially since structures to control the water level are already in existence.

5. Lake Bottom Sealing

A technique to prevent the release of nutrients and metals from the lake sediments to the overlying waters is the covering or sealing of the lake bottom. A variety of materials exist which are suited for this purpose. The list includes sand, gravel, silt, clay, silica, nontoxic mine tailings, flyash or sheets of manmade material.

Depending on the nature of the sealing material, the existing habitat may be made less available to various bottom dwelling organisms. Gravel layers and plastic sheeting can be expected to prevent burrowing animals from utilizing the bottom muds. The timing of deposition is crucial since eggs may be covered resulting in a long-term negative impact on zooplankton, zoobenthos, and fish species. If the sealant is contaminated or is not adequately prepared and treated, potentially toxic materials may be released to the aquatic ecosystem. Flyash, for example, contains potentially toxic heavy metals which include boron, molybdenum, selenium, arsenic and mercury. The use of synthetic liners made of polyethylene, polypropylene and synthetic rubber requires that these materials be weighted and perforated to allow for the escape of gases which otherwise would lift the liner from the lake bottom. At the same time these perforations will also allow plants to grow through them. Silt that is deposited can acculumate on the sheeting permitting new plants to grow.

Cost is dependent on the material used, the method of application and transportation distance. Materials such as sand, gravel,clay and flyash will vary in price as to the local availability of these substances. Synthetic linings range in price from $200 to $20,000 per acre.

6. Phosphorus Precipitation/Inactivation

Phosphorus precipitation/inactivation is a technique that will lower phosphorus concentrations in the water column and thereby control the amount of planktonic algae. Aluminum compounds,principally aluminum sulfate,are utilized for this purpose. Phosphorus may be removed from the water column by precipitation but more importantly, a phosphorus-sorbing floc of aluminum hydroxide $Al(OH)_3$ is formed which will prevent the release of phosphorus from the nutrient rich sediments. This treatment in several lakes has resulted in reduced phosphorus concentrations, a decrease of nuisance algae and an adequate supply of dissolved oxygen. The ability of the deposited aluminum hydroxide to retain phosphorus at the sediment-water interface will determine its long-term effectiveness.

Very few systematic investigations have been undertaken to determine the toxicity of aluminum to aquatic populations or communities. In the dissolved form, aluminum could be hazardous and the amount which will appear in the water column after treatment is pH dependent.

For this procedure to be effective, significant inputs of nutrients must be eliminated. It is quite successful in controlling algal populations but has little control over rooted macrophytes, ruling out its application on Flint Pond.

Adequate cost information is unavailable as treatments differ and costs for labor and equipment vary. It has been reported that equipment and chemicals can average between $400 to $500 per hectare (1980 dollars) with labor amounting to one to two man-days per hectare.

7. In-Lake Aeration

The amount of organic matter from sources such as dead algae, weeds, animal feces, etc. that enters the hypolimnion can be quite extensive. This material is decomposed by bacteria which utilize dissolved oxygen in the process. Low dissolved oxygen conditions result in nutrients being released from bottom sediments and the accumulation of compounds such as hydrogen sulfide, methane, manganese and iron. The deep coldwater becomes an unsuitable habitat for cold water fish, such as trout, because of the low dissolved oxygen. Algal blooms may develop as nutrients are mixed into the epilimnion at turnover.

Two prodecures that may be utilized to combat low dissolved oxygen concentrations are hypolimnetic aeration and artificial circulation. Hypolimnetic aeration introduces air or oxygen into the hypolimnion without any disruption of thermal stratification, whereas the air in artificial circulation is introduced with sufficient force to cause a mixing of the entire water column.

Hypolimnetic aeration is most commonly accomplished by an air-lift system in which compressed air is injected into the hypolimnion.Water is forced up a tube to the lake surface and then returned to the hypolimnion by the same tube (Figure IV-6). Oxygenation and loss of hydrogen sulfide, ammonia and other gases occurs at the top of the air-lift tube at the lake surface. In this manner the cold water fishery may be expanded and winter fish kills averted. Phosphorus concentrations may be lowered in the hypolimnion but there is little evidence that a concomitant decline of algae occurs in the epilimnion.

Artificial lake circulation or destratification is accomplished by injecting air at a high rate through a perforated pipe into the deepest portion of the lake (Figure IV-7).Once circulation is completed this apparatus is used intermittently. This method removes the same compounds as hypolimnetic aeration. Phosphorus levels may decline but this effect on algal biomass has been variable.

Destratification may benefit a warmwater fishery by expanding the habitat and abundance of fish food organisms. Several negative impacts may occur including increased turbidity if sediments are disturbed, stimulation of an algal bloom by bringing nutrients into upper lighted waters, creation of gas bubble disease in fish from increased dissolved nitrogen concentration in the water, and fish kills from a sudden decrease in dissolved oxygen in the epilimnion following the introduction of oxygen-free hypolimnetic waters to the rest of the lake.

In Lake Quinsigamond dissolved phosphorus has been identified as the key parameter causing oxygen depletion in the hypolimnion. Since there is a great deal of difficulty involved in controlling dissolved phosphorus it might be wise to address the dissolved oxygen problem directly by in-lake aeration. Since the coldwater fishery is a vital recreational activity in Lake Quinsigamond it is important to avoid upsetting the temperature stratification. Artificial lake circulation would create an identical temperature within the lake from top to bottom making it too warm to support the coldwater fishery and too cold for contact sports such as swimming and water skiing. Hypolimnetic aeration would be effective in maintaining dissolved oxygen in the hypolimnion

HYPOLIMNETIC AERATION SYSTEM *

*(Fast, 1979)

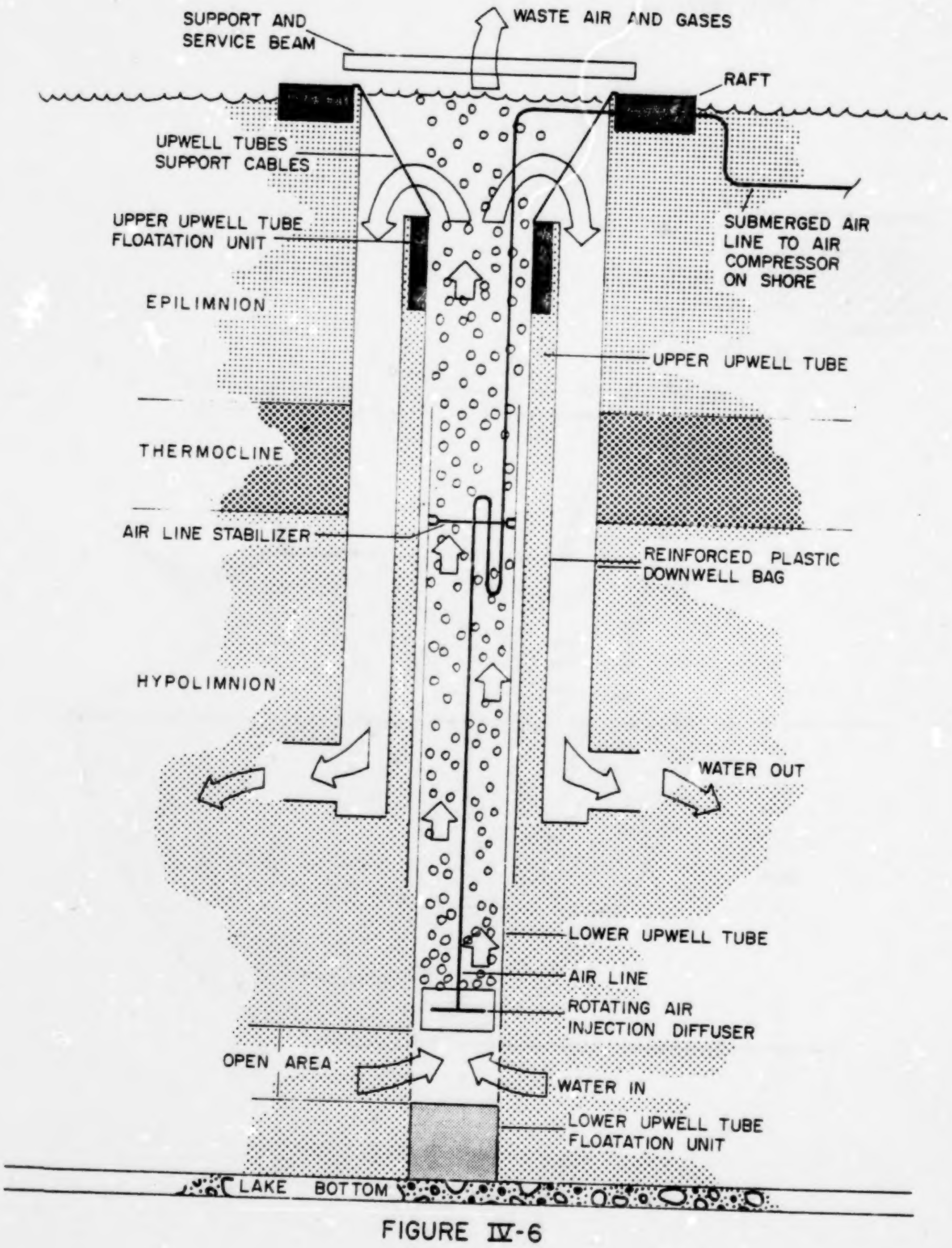
SUPPORT AND SERVICE BEAM
WASTE AIR AND GASES
RAFT
UPWELL TUBES SUPPORT CABLES
UPPER UPWELL TUBE FLOATATION UNIT
SUBMERGED AIR LINE TO AIR COMPRESSOR ON SHORE
EPILIMNION
UPPER UPWELL TUBE
THERMOCLINE
AIR LINE STABILIZER
REINFORCED PLASTIC DOWNWELL BAG
HYPOLIMNION
WATER OUT
LOWER UPWELL TUBE
AIR LINE
ROTATING AIR INJECTION DIFFUSER
OPEN AREA
WATER IN
LOWER UPWELL TUBE FLOATATION UNIT
LAKE BOTTOM

FIGURE IV-6

ARTIFICIAL CIRCULATION*

*(Fast, 1979.)

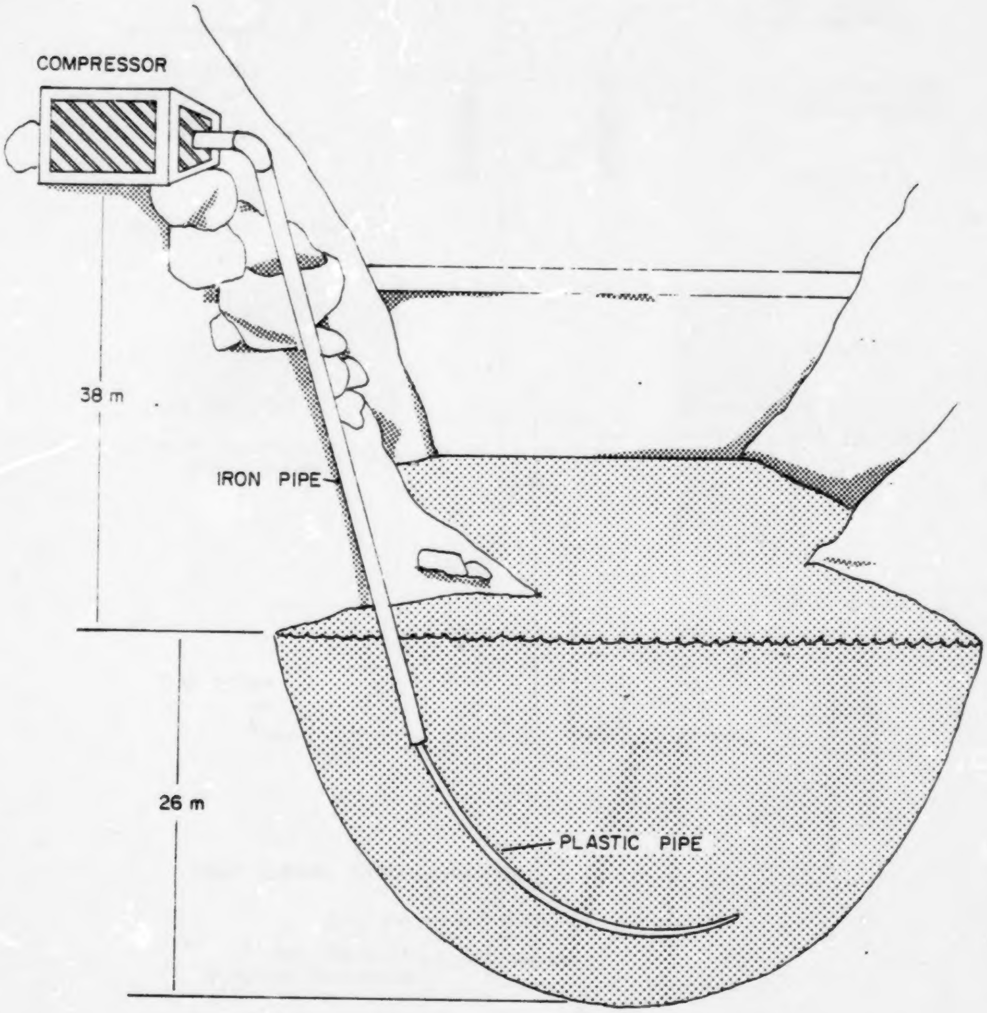
COMPRESSOR
38 m
IRON PIPE
26 m
PLASTIC PIPE

FIGURE IV-7

during the critical summer months. Aeration could increase the habitable zone for fish and decrease the amount of metal recycling from the bottom sediments. The lake would likely need three aerators to correspond to its three major basins.

The capital outlay for this type of device is in the range of $3,000 to $10,000 while operation and maintenance costs can average between $6,000 to $10,000 per year.

V. Recommended Watershed Management Plan for Lake Quinsigamond and Flint Pond

A. Management Objectives for Water Quality and Use

Having evaluated the water quality problems in the watershed and defined the alternative measures available to address those problems, it is necessary to re-examine the water quality objectives defined at the program's outset; re-define those objectives as warranted by the findings of the program; and define the major elements of a control plan required to achieve those objectives. Water quality management objectives for the Lake Quinsigamond/Flint Pond drainage area can be defined as follows:

1. Maintain highest level of water quality required to support current uses, (i.d., all recreational uses).
2. Maintain or upgrade all surface water in the drainage basin at a minimum acceptable level of Class B water quality.
3. Protect all primary and secondary water supply growndwater aquifers from contamination/degradation; and
4. Preserve remaining wetlands for flood storage/release and pollutant attenuation.

Broadly stated, the above objectives are summarized in the following statement:

> Improve/maintain water quality conditions to provide the maximum utilization of the most significant natural resource in the Central Massachusetts region for the most appropriate beneficial uses of Lake Quinsigamond, Flint Pond and other water bodies in the watershed.

Based on the water quality assessment and pollutant source inventory described in Chapters II and III respectively, specific water quality goals can be identified for Lake Quinsigamond/Flint Pond as follows:

1. Protect beach areas from bacterial pollution;
2. Provide 200-day hypolimnetic oxygen supply during stratification to increase cold-water fisheries habitat; reduce internal cycling of nutrients and heavy metals, and reduce occurrences of blue-green algae populations.
3. Control/limit growth of nuisance aquatic weeds (Flint Pond and Lake Quinsigamond above Main Street, Shrewsbury);
4. Limit/reduce sedimentation and sandbar formation in near-shore areas; and

5. Maintain a minimum 4 foot secchi depth, in accordance with State Regulations.

Any proposed control/management program designed to achieve these goals must therefore include the following elements:

1. Control of bacterial pollution sources;
2. Control of nutrients (particularly dissolved phosphorus);
3. Control of internal cycling of nutrients and heavy metals;
4. Control of aquatic weeds;
5. Control of erosion and sedimentation; and
6. Control of heavy metals.

Prior to the development of a control plan, it is important to consider the interrelationships of the program elements identified above in terms of water quality parameter interactions; pollution sources; control alternatives and the ability of various control strategies to achieve the stated water quality goals and objectives. The following sections discuss each of the program elements identified above.

Control of Bacterial Pollution Sources

Bacterial pollution is widespread throughout the basin. Bacterial pollution has led to the impairment of both the Lake and several of its tributaries for recreational uses including swimming and fishing. Due to re-construction of a major trunk sewer and the diversion of stormwater runoff from the Route 9 storm drain away from the Regatta Point Beach, in-lake bacteria levels have not resulted in any beach closings in the last four years. However bacteria levels in Poor Farm Brook have led to reduced fish stocking by the Division of Fisheries and Wildlife. Bacteria levels in Coal Mine Brook have resulted in the permanent closing of a major groundwater supply well at the mouth of the brook.

In terms of control strategies, either disinfection of stormwater discharges and major tributaries (including Route 9 drain, Poor Farm, Coal Mine, Fitzgerald, O'Hara and Tilly Brooks) or a program of source identification and correction are required. Source identification and correction has several advantages over disinfection including cost, impacts on aquatic life and secondary benefits in terms of solids and nutrient reductions. A third option is regulatory control to protect public health. Under this option, the beach areas would automatically be closed following rain storms of specified magnitude and duration. It will likely be necessary to consider additional options in order to recover use of the Coal Mine Brook pumping station including source controls plus diversion of surface flow away from the well field.

Nutrient Control - External Sources

Control of dissolved phosphorus and biologically-available particulate phosphorus have been identified as key nutrients controlling eutrophication, algal growth and depletion rate of hypolimnetic oxygen. Model estimates indicate that reductions of dissolved phosphorus of 50 to 80% are required to meet the water quality goal of maintaining a 200 day hypolimnetic oxygen supply. Control of stormwater alone is not likely to achieve this goal as only a portion of the total runoff in the basin, which accounts for 67% of the dissolved phosphorus load, can be expected to be controlled or treated. Further,lake modeling (see Chapter III section 4d) indicated that, under projected future land use conditions and a control scenario providing 75% particulate control and 50% runoff volume control, the 200 day objective would very nearly be met (196 days).

Major control alternatives include particulate control (either source control or treatment of runoff), runoff volume reduction (storage or groundwater recharge), runoff diversion (collection and pumping to the Quinsigamond or Blackstone River) and in-lake measures such as the Dunker's pontoon system, chemical treatment or in-lake aeration. In terms of effectiveness, particulate control will not likely result in significant reductions of either particulate or dissolved phosphorus. It is important however to recognize that particulate controls may have a significant impact in reducing the solids and heavy metals loads to the lake which are also major control program elements (control of erosion and sedimentation and control of heavy metals). Runoff volume reduction may have a significant impact on reducing dissolved phosphorus levels in addition to particulates and other dissolved constituents. However, due to both the limited availability of land in the vicinity of the most heavily developed areas and physical characteristics, this approach may be of somewhat limited applicability. Runoff diversion by collection and pumping is both costly and difficult and not particularly practical from either an engineering or environmental point of view. In-lake measures such as chemical treatment may alleviate some of the symptoms of lake eutrophication on a short term basis but unless pollution sources are addressed additional treatment will undoubtably be required. In-lake aeration may enable the lake to meet the 200-day hypolimmetic dissolved oxygen goal in addition to limiting internal cycling of nutrients and metals. However cost, operational responsibility, and monitoring requirements to prevent upsetting the temperature stratification thus protecting the cold-water fishery are vital considerations with regard to this option.

Control of Internal Cycling of Nutrients and Heavy Metals

As discussed in the water quality analysis of the lake, internal cycling of nutrients is not a major factor in the main body of Lake Quinsigamond due to favorable geomorphic characteristics and the availability of iron which complexes the phosphorus and re-settles. However, in Flint Pond and the small shallow northern basin of Lake Quinsigamond (above Main Street, Shrewsbury), internal nutrient cycling is a major factor affecting the growth of aquatic weeds. Several available control alternatives are equally applicable to both problems. Such alternatives include chemical treatment, dredging, and artificial liners. Due to the relationship between internal cycling and growth of aquatic weeds, these control alternatives must be considered concomittant with weed control alternatives.

Control of Aquatic Weeds

As previously described, aquatic weeds are a major problem in Flint Pond and in the shallow northern basin of the lake. In addition to the control alternatives listed above, which apply to both aquatic weeds and nutrient cycling, alternatives applicable to the control of aquatic weeds include harvesting and lake drawdown. Generally, chemical treatment, weed harvesting and lake drawdown provide only temporary relief of rooted aquatic vegetation. Given the available sediment nutrient reservoir,these techniques offer little toward the improvement of Flint Pond. Dredging and use of artificial liners both warrant serious consideration. Also, serious consideration should be given to modifications of the hydraulics of Flint Pond towards improving flushing characteristics and limiting settleability in open water areas of the pond's three major basins.

Control of Erosion and Sedimentation

Control of erosion and sedimentation can yield significant improvements in terms of both solids and nutrients. Control alternatives include land treatment measures, stream and pond bank stabilization, in-line and off-line storage of base and/or storm runoff flows, land use control and regulatory measures as well as land-based particulate controls (i.e., street sweeping, catch basin cleaning, leaf and litter pick-up) previously discussed. Much of the success of these controls is dependent on the ability and committment of responsible authorities to enforce regulations and maintain adequate operation and maintenance programs.

Control of Heavy Metals

The most significant sources of heavy metals to the lake are transportation-related. These include vehicle emissions, fuel and lubrication products, certain washing and cleaning compounds, tire construction materials, highway construction materials, road and highway de-icing compounds and related activities, and materials scoured from vehicles during rain storms. Although the impacts of heavy metals on the water quality of the lake are not fully understood at this time, some control over the sources of heavy metals may be realized through control measures discussed under erosion and sedimentation and particulate controls. Additional study of heavy metals in the lake ecosystem is required.

Based on the stated water quality goals and management objectives, and with regard to the considerations enumerated above, the following sections describe the recommended watershed management program including Lake Quinsigamond, Flint Pond and their tributaries. Although presented in three sections, these recommended actions are intended to serve as a comprehensive watershed management plan for the entire Lake Quinsigamond-Flint Pond drainage area.

B. Lake Quinsigamond Management Plan

Based on the assessment of the importance of controlling nutrient and solids stormwater loads under future projected land use conditions throughout the drainage area, it is important to consider the adoption of appropriate development guidelines and regulatory controls throughout the watershed. Such regulatory controls are a critical element in any management plan which expects to be successful in meeting long-term water quality objectives. It is therefore recommended that the towns of West Boylston,Boylston, Shrewsbury and Grafton and the City of Worcester 1) develop and implement ordinances and by-laws as appropriate to control erosion and sedimentation from all earth disturbing activities within their jurisdiction and 2) require that all developments involving greater than 25,000 square feet provide infiltration capacity for a minimum of 0.50 inches of rainfall and that the development will not result in any net change in either the quantity of runoff or the rate of runoff from a site prior to the proposed development. With these plan elements in effect, identified discrete problems can be addressed. These components discussed in the following sections.

Belmont Street Drain

The Belmont Street Drain consists of an extensive storm drainage system of over 335 acres (see Figure V-1). The drainage area extends from Holmes Field on Plantation Street to Harrington Field to Belmont Street and finally,-to the discharge on the north side of the Route 9 bridge. Pipe sizes in the storm sewer network range from 10 to 60 inches. The discharge consists of a 60-inch submerged box culvert with a 36-inch overflow pipe.

The discharge from this system is the single most visible pollution source to Lake Quinsigamond. As determined in both the lake and stormwater sampling programs, the system is a significant source of bacteria, solids, nutrients and heavy metals. Due to the impact of high bacteria levels at the Regatta Point beach, which resulted in frequent beach closings in the 1960's and early 1970's, a gravel coffer dam was constructed between the shoreline and the first off-shore bridge support pier. The discharge is thus routed under the bridge through the channel between the Worcester shore and Ramshorn Island and into Lake Quinsigamond's southern basin. Although this measure has served its purpose in protecting the swimming areas from bacterial pollution, the receiving channel has deteriorated noticeably. Bacteria and other pollutant levels remain high.

A variety of control strategies are applicable in this drainage system. These include the following:

In-line: Structural

- In-line dentention/storage: oversize pipe, hydro-brakes, perforated pipe or combinations of these.

In-line: Non-Structural/Source Control

- Storm and sanitary sewer inspection program
- Street sweeping/catch-basin cleaning

Stormwater Treatment

- Swirl concentrator /solids separator
- Dunker's in-lake detention/treatment system
- Sedimentation basins

Optional Corollary Actions

- Construct permanent berm or other channel diversion

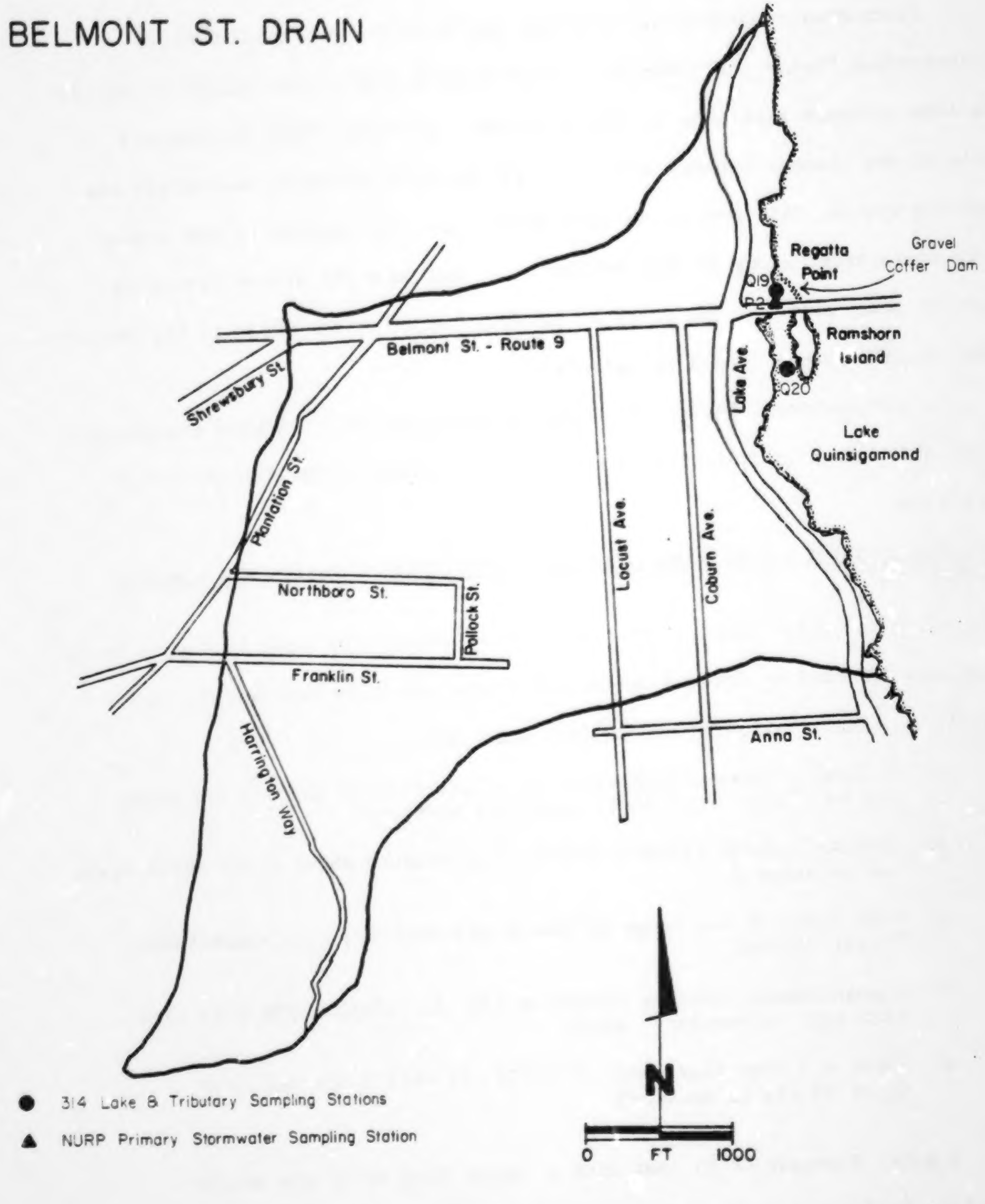
BELMONT ST. DRAIN
Gravel Coffer Dam
Regatta Point
Q19
P2
Ramshorn Island
Q20
Lake Quinsigamond
Lake Ave.
Belmont St. - Route 9
Shrewsbury St.
Plantation St.
Locust Ave.
Coburn Ave.
Northboro St.
Pollock St.
Franklin St.
Harrington Way
Anna St.
N
0 FT 1000
0 KM 1
● 314 Lake & Tributary Sampling Stations
▲ NURP Primary Stormwater Sampling Station

FIGURE V-1

- Extend outfall
- Dredge receiving channel

Stormwater treatment alternatives listed above were evaluated by Environmental Design and Planning. Sedimentation basins were ruled out due to the lack of space available at this location. Although there is adequate space in the channel between Worcester and Ramshorn Island to accomodate the Dunker's system, this system was also ruled out. The concept of the system is to store storm flows in the baffles and pump the stored liquid to sanitary sewer line. The costs of pumping to raise the water to the sanitary sewer on Lake Avenue would be excessive.

Environmental Design and Planning developed the following preliminary design and cost information for a swirl concentrator at the Belmont Street Drain site.

Swirl Concentrator - Preliminary Design - Environmental Design and Planning, September, 1981

Flow and water quality for the 29 storm events monitored by Environmental Design and Planning at Route 9 during 1980 were carefully reviewed in this connection. The following conclusions were drawn:

a) Following storm events there is a base flow of about 2 cfs which can be ignored from water quality standpoint.

b) Similarly, small rainfall events also produce about 2 cfs which again can be ignored.

c) Peak flows in the range of 50-100 cfs contribute to significant "first flushes".

d) Instantaneous flows in excess of 100 cfs (highest 250 cfs) have been very infrequently noted.

e) Thus, a design flow range of 2-100 cfs with a nominal flow, Q_D of 50 cfs is selected.

A swirl diameter of 25 feet with a design flow of 50 cfs should adequately handle the desired flow range. A Hydro-brake^R of 100 cfs would limit flow to the swirl. All flows up to 2 cfs would continue to the Lake by placement of small brick weir within the divider manhole. A Hydro-brake^R within a new junction chamber would only permit up to 100 cfs to continue to the new treatment facility. All other flow would be bypassed to the lake (with floatables trapped and sent to the swirl for capture). A Hydro-brake^{R} placed on the swirl underflow would limit discharge to a maximum of 2.5 cfs (5% of Q_D).

A review of the relative invert information for the Belmont Street trunk storm drain (354.4' where drain splits) and the 42 inch sanitary trunk sewer (338.7') indicates that there exists a suitable situation for treating "first flush" storm drainage with swirl and then allowing the foul underflow from the swirl to be diverted by gravity to the trunk sanitary sewer. Since the 42 inch sanitary trunk sewer is on a relatively flat slope (about .0009) it is adviseable to first remove the heavy settleable sand, gravel, and grit from the swirl foul underflow.

To accomplish this aim it is proposed to put a swirl degritter on the swirl underflow and allow the supernatant from the degritter to discharge by gravity into the 42 inch sanitary trunk sewer. A flow of about 2.25 cfs will occur when the unit is in operation. Only the light organic settleables and floatables will be removed. It is assumed that there is adequate conveyance capacity in the 42 inch sanitary trunk to handle the additional 2.25 cfs of wet weather flow.

Two options remain for the heavy grit/sand/gravel waste stream from the swirl degritter:

a) Mechanical removal by screw into dumpster for pick up and land-fill disposal.

b) Direct discharge down to the lake (or into small underground pump for biannual removal).

Approximate capital costs for a minimum level facility (degritter solids to lake) are as follows:

Description	1981 Dollars
Inlet chamber	45,000
Swirl/solids cnncentrator(25 ft. dia.)	150,000
Swirl degritter w/out solids removal	50,000
Piping/outlet structure	50,000
Fencing/landscaping/access road	50,000
	345,000
15% contingency	52,000
	397,000
15% engineering, legal and admin.	60,000
TOTAL	$ 457,000

It is expected that the envisioned facility would remove 75-80% of all floatable material presently discharged and between 25-40% of all suspended solids presently being discharged.

Given the importance of bacterial control, a storm and sanitary sewer inspection program using TV equipment, visual inspection and dye tracer studies as appropriate should be conducted jointly by the City Departments of Public Works and Public Health. Corrective action on problems so identified should be initiated immediately.

Street sweeping and catch basin cleaning are already conducted in the area. These practices should be evaluated and targeted to major flood control and pollution control areas within the system as may be identified in the sewer system inspection program.

The use of Hydro-brakes^R in conjunction with either oversize or perforated steel or aluminum pipe could be very effective in achieving stormwater volume control. The Hydro-brakes^R would be used to control flow into the system. The pipe would serve as either a detention basin (oversize pipe) or as a recharge/infiltration basin (perforated pipe). Candidate areas for this control alternative include the 60-inch stormwater line on Locust Avenue and the 48-inch line between Wells Street and Wigwam Avenue near the Providence and Worcester Railroad line. It is recommended that this alternative be further explored to develop preliminary design and cost information. This alternative can then be compared to the swirl concentrator.

Optional corollary actions were identified to improve the condition of the receiving water channel in anticipation of improved stormwater quality characteristics. It is recommended that the gravel coffer dam remain in place to continue to direct runoff under the Route 9 bridge away from the beach areas. It is also recommended that the channel be dredged to a depth at least three feet below the invert elevation of the 60-inch submerged outfall from the outfall to the mouth of the channel. This will allow more complete and frequent flushing of the channel and eliminate the ponding characteristics which occur at the discharge on the north side of the bridge. Extending the outfall should not be considered any further at this time until a decision has been made with regard to treatment and/or control alternatives discussed above.

Lake Quinsigamond,(North of Main Street, Shrewsbury)

The major problems identified in this area include sediment buildup and excessive weed growth. These problems are the result of nutrient and solids loads from Poor Farm Brook and erosion from the Worcester Sand and Gravel Company operation. The total area of the pond is about 23 acres. Two areas within the pond, designated areas A and B in Figure V-2, have been identified as target areas for in-lake control.

Area A is approximately 10 acres in size. Probe measurements indicate an average sediment depth of about 3 feet which yields a sediment volume of about 48,400 cubic yards. Area B is about 6 acres in size with an average sediment depth of about 2 feet yielding a sediment volume of about 19360 cubic yards. The sediment in both areas consists primarily of clean sand and gravel. Area B also includes a substantial build-up of organic matter.

Dredging and weed harvesting appear to be the most applicable control alternatives for this area. Benefits associated with both alternatives include improvements to fisheries and wildlife habitat, enhanced recreational capacity, and aesthetic improvements with respect to pond abutters and property owners. Advantages associated with dredging include long-term control effectiveness, restoration of depth in sediment-clogged channels, improved safety via the removal of unconsolidated silt, sand and gravel, and improvements of flow characteristics through the pond. Disadvantages include cost,short-term disruption of fish and wildlife habitat, noise, transportation, treatment (if necessary) and disposal of dredged material and increased turbidity and dissolved solids. Advantages associated with weed harvesting include cost,reductions in aquatic weed densities and the ability to focus in a specific area. Disadvantages include potential

LAKE QUINSIGAMOND - NORTHERN POND
(Above Main Street Shrewsbury)

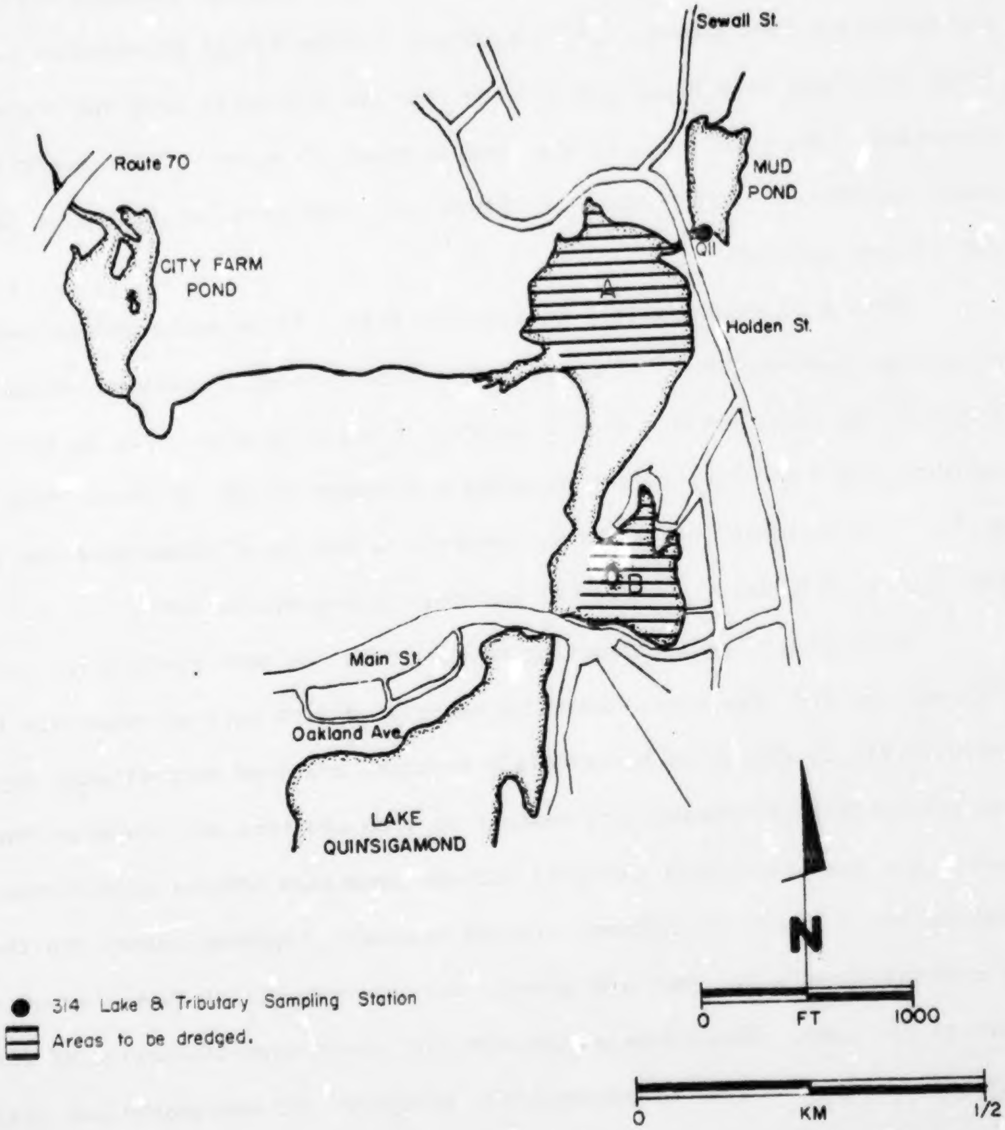
Sewall St.
Route 70
MUD POND
CITY FARM POND
Q11
A
Holden St.
B
Main St.
Oakland Ave.
LAKE QUINSIGAMOND
N
0
FT
1000
0
KM
1/2
● 314 Lake & Tributary Sampling Station
Areas to be dredged.

FIGURE V-2

LAKE QUINSIGAMOND - NORTHERN POND
(Above Main Street Shrewsbury)
AQUATIC PLANT
DISTRIBUTION

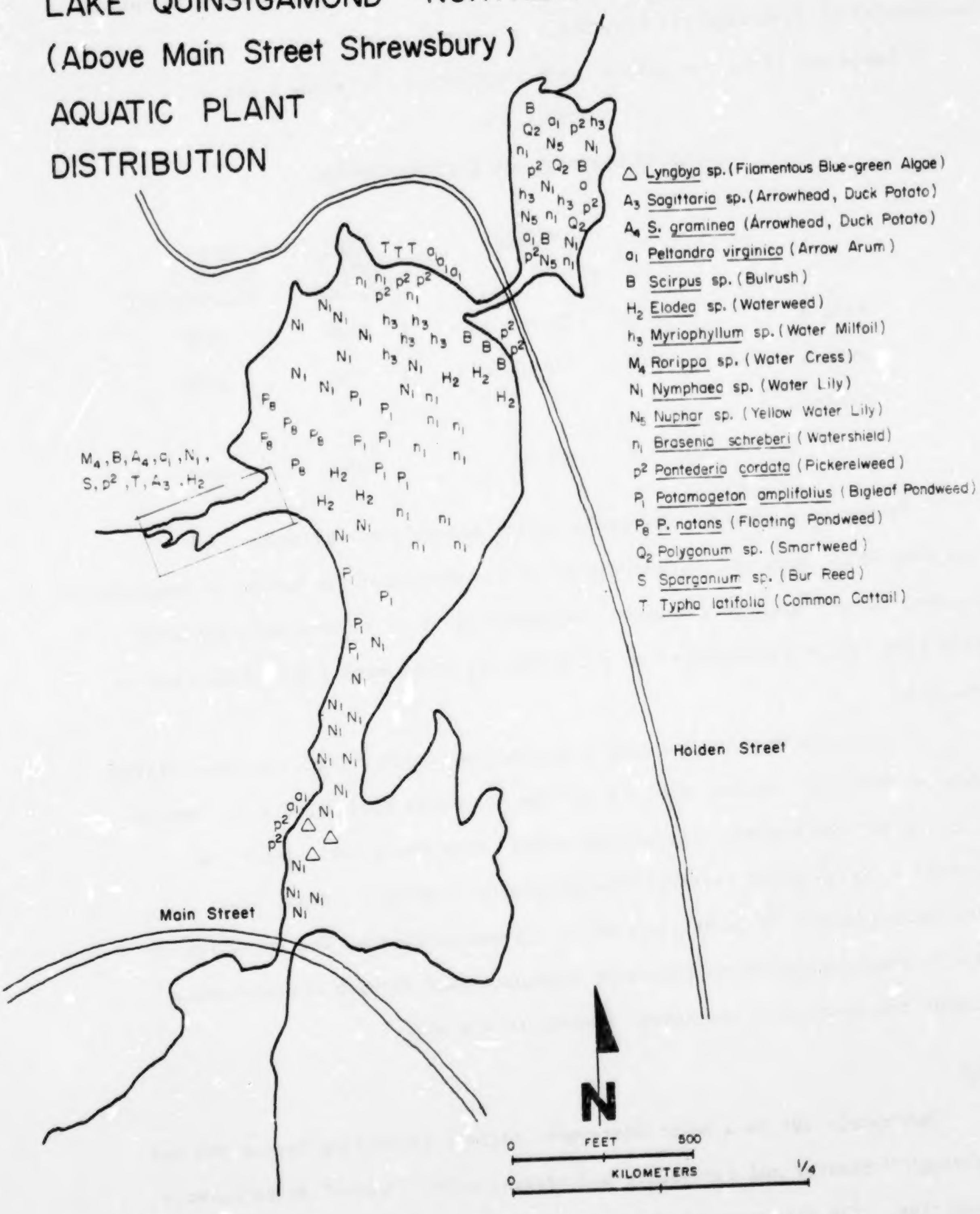
△ Lyngbya sp. (Filamentous Blue-green Algae)
A_3 Sagittaria sp. (Arrowhead, Duck Potato)
A_4 S. graminea (Arrowhead, Duck Potato)
a_1 Peltandra virginica (Arrow Arum)
B Scirpus sp. (Bulrush)
H_2 Elodea sp. (Waterweed)
h_3 Myriophyllum sp. (Water Milfoil)
M_4 Rorippa sp. (Water Cress)
N_1 Nymphaea sp. (Water Lily)
N_5 Nuphar sp. (Yellow Water Lily)
n_1 Brasenia schreberi (Watershield)
p^2 Pontederia cordata (Pickerelweed)
P_1 Potamogeton amplifolius (Bigleaf Pondweed)
P_8 P. natans (Floating Pondweed)
Q_2 Polygonum sp. (Smartweed)
S Sparganium sp. (Bur Reed)
T Typha latifolia (Common Cattail)
M_4, B, A_4, a_1, N_1, S, p^2, T, A_3, H_2
Holden Street
Main Street
N
0 FEET 500
0 KILOMETERS 1/4

FIGURE V-3

for regrowth, the need to harvest on a continuing basis, ineffective with regard to sediment build-up, and disposal of harvested material and elimination/ destruction of fish/wildlife habitate.

Table V-1 lists the cost of each alternative for areas A and B.

TABLE V-1

COSTS OF DREDGING AND WEED HARVESTING

	Dredging	Weed Harvesting	
		Own Equipment	Contract for services
Area A	$ 193600	$ 1000	$ 3000
Area B	$ 77440	$ 600	$ 1800
Other			
TOTAL	$ 271040	$ 1600	$ 4800

Taking into account expected nutrient and solids load reductions from Poor Brook Farm via implementation of its watershed management recommendations, the cost factors and the projected improvements, it is recommended that weed harvesting should be conducted on a contractual basis with a qualified firm in this area.

It is also recommended that a minimum twenty-five foot vegetated buffer strip be developed between the pond and the Worcester Sand and Gravel Company. It is further recommended that surface runoff from the gravel company be diverted to groundwater recharge via perforated aluminum or steel pipe, infiltration basins or other percolation/filtration device. The objective of these recommendations is to reduce or eliminate wind erosion and stormwater sediment transport from the gravel company to the pond.

I-290

Interstate 290 is a major east-west highway connecting Routes 495 and 52 through Worcester and Shrewsbury and several other Central Massachusetts communities. The alignment of the highway through Worcester and Shrewsbury traverses several tributary drainage areas and includes a major lake crossing over the northern lake basin. Average daily traffic volume in the section from Lincoln Street to Plantation Street in Worcester during 1980 was 45,500 vehicles. In the section west of Route 140 in Shrewsbury to Plantation Street in Worcester the daily traffic volume averaged 34,200 in 1980 .* Three major pollution sources can be associated with the highway. They are the highway itself including maintenance and repair activities and the application of sand and chemicals for snow and ice control, and the vehicles which utilize the road.

Regular maintenance activities conducted by the Massachusetts Department of Public Works (MDPW) include sweeping and catch basin cleaning; ditch spraying and the application of a soil sterilant to prohibit vegetation around guardrails.

It is recommended that MDPW increase the frequency of sweeping on the bridge deck, east and west bound lanes from the Lake to Burncoat Street and on and off-ramps on Plantation Street during the early spring as weather conditions permit.

It is recommended that the concrete drainage ditch (see Figure V-4) along the North side of the westbound lane between the road and Lincoln Plaza be replaced by a perforated channel with infiltration trenches and that a sedimentation infiltration basin be constructed at the inlet to the culvert running under the highway to Coal Mine Brook.

It is recommended that MDPW enter into a cooperative venture with the City of Worcester to divert the Lincoln Street-Plantation Street storm sewer at the drainage ditch along the north side of I-290 between Plantation Street and the Lake and replace the ditch and storm sewer diversion with a perforated pipe infiltration system.

It is recommended that the drainage ditch along the south side of I-290 between Plantation Street and the Lake be replaced with a perforated pipe infiltration system.

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* DPW - District 3 Traffic Court - 1980

COAL MINE BROOK, I-290

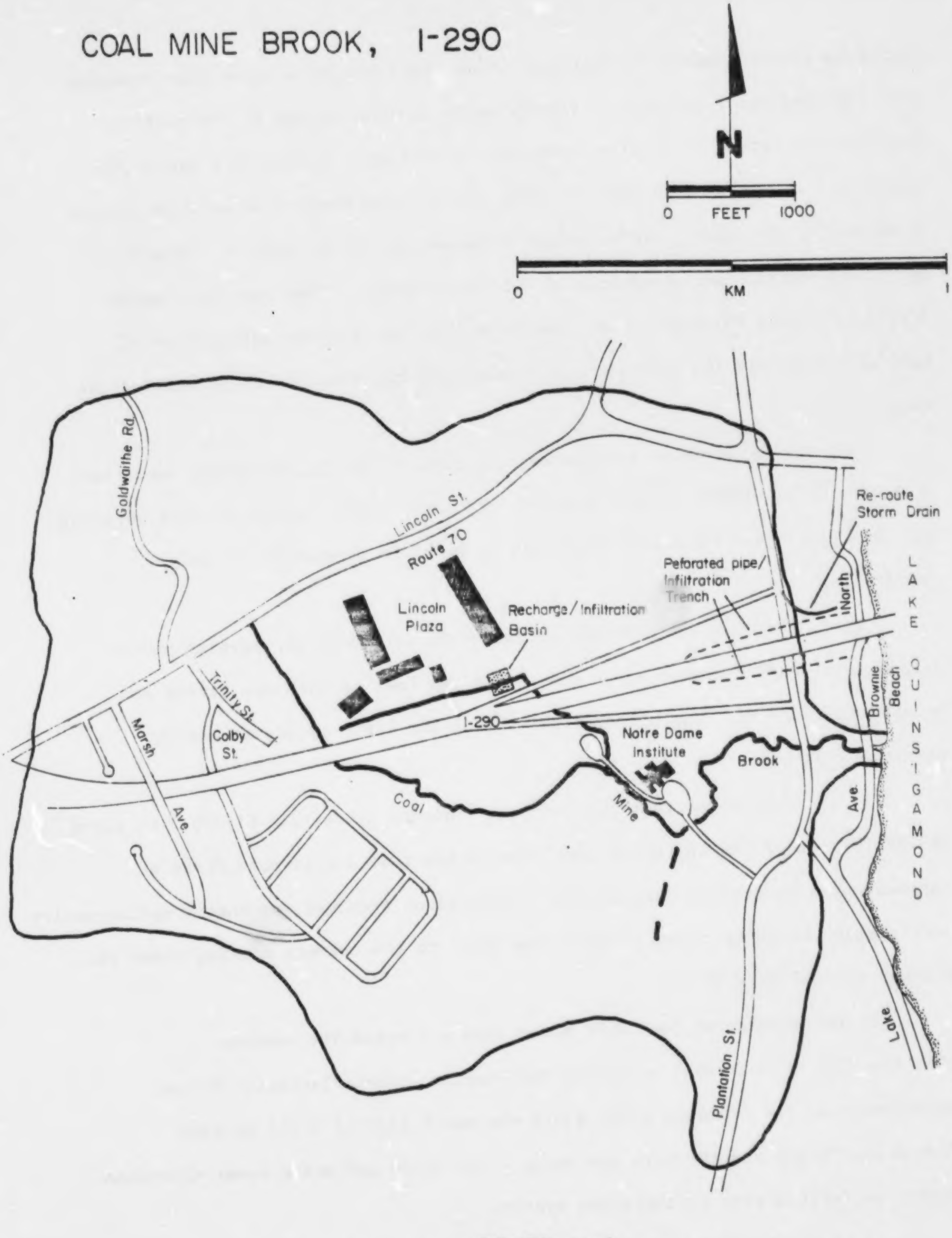

N
0
FEET
1000
0
KM
1
Goldwaithe Rd.
Lincoln St.
Route 70
Lincoln Plaza
Recharge/Infiltration Basin
Peforated pipe/ Infiltration Trench
Re-route Storm Drain
North
LAKE QUINSIGAMOND
Brownie Beach
Trinity St.
Colby St.
Marsh Ave.
I-290
Notre Dame Institute
Coal Mine Brook
Ave.
Plantation St.
Lake

FIGURE V-4

Parking Lots and Boat Ramps

There are several major parking lots serving both commercial and industrial complexes throughout the drainage basin. These include Lincoln Plaza, Caldor Plaza, Lincoln Village, Sheraton-Lincoln, Goddard Industrial Park, Fallon Clinic, University of Massachusetts Medical School, White City Plaza, South Worcester Plaza, and Wyman-Gordon Company. Boat ramps on Lake Quinsigamond include Coal Mine Brook ramp, Regatta Point, ITAM Club lot, and the ramp operated by Fleet Marine. A new ramp is planned by the Department of Environmental Management to be located in Shrewsbury, across the lake from the Coalmine ramp. Boat ramps on Flint Pond include Gauch Marine and the Department of Environmental Management ramp on Route 20. These areas all have in common their association with automobiles and other aspects of transportation-related pollutant sources. Based on that association, the following recommendations are made applicable to parking lots and boat ramps:

Parking lots

- Parking lots should be dry-swept or vacuum cleaned at least once every twelve to fifteen days.
- Drainage systems serving existing lots should be evaluated to determine the feasibility and costs of retro-fitting the systems with perforated pipe or other infiltration device.
- Construction of new parking lots or expansion/modification of existing lots should be required to provide infiltration capacity to accommodate 0.50 inches of rainfall.
- Plowing of snow directly into the lake or any tributary should be prohibited. Provisions for snow removal and dumping at a site removed from these water bodies with good soil permeability should be made.

Boat Ramps

- Boat ramps and associated parking areas should be dry-swept or vacuum-cleaned at least once every twelve to fifteen days during periods of active use.
- Litter receptacles should be provided and emptied frequently at all facilities.

- Facilities for the receipt of waste oil are required by law at all outlets where such materials are sold. Such facilities should either be provided at all boat ramps or a list of facilities available to the public should be made available at all boat ramps.
- Laws and regulations regarding littering and the disposal of waste oil and other materials should by strictly enforced.

C. Flint Pond Management Plan

Flint Pond is a shallow, unstratified pond consisting of three basins. Figure V-5 shows the major features of the pond. The northern basin is connected to Lake Quinsigamond via the Stringer Dam. This basin has a maximum depth of about 10 feet and has a surface area of about 118 acres. A sizable cove of nearly 25 acres extends up to South Quinsigamond Avenue and the outlet of South Meadow Brook. Three small islands are located near the easterly shore of the basin. The northern basin connects to the middle and southern basins under Route 20.

The middle basin has a maximum depth of about 13 feet and a surface area of approximately 92 acres. This basin receives inflow from the northern basin at Route 20 and via a direct connection with Lake Quinsigamond at Route 20. A privately owned recreation and swimming area known as Point Rock is located on the southeastern shore of this basin. A public boat ramp is located on Oak Island, a fairly large peninsula south of Route 20. An elongated peninsula extending northward from the town of Grafton separates the middle and southern basins. A New England Power Company power line crosses the pond along this peninsula. The outflow from both the northern and middle basins circulates around the end of this peninsula and enters the southern basin. The southern basin has a maximum depth of about 6 feet and a surface area of about 58 acres. This area includes a cove and backwater area of about 8 acres at the southern end of the pond which receives the discharge from Bonnie Brook .

As discussed in other sections of the report, the major problems affecting Flint Pond are the proliferation of aquatic weeds in addition to nutrients and

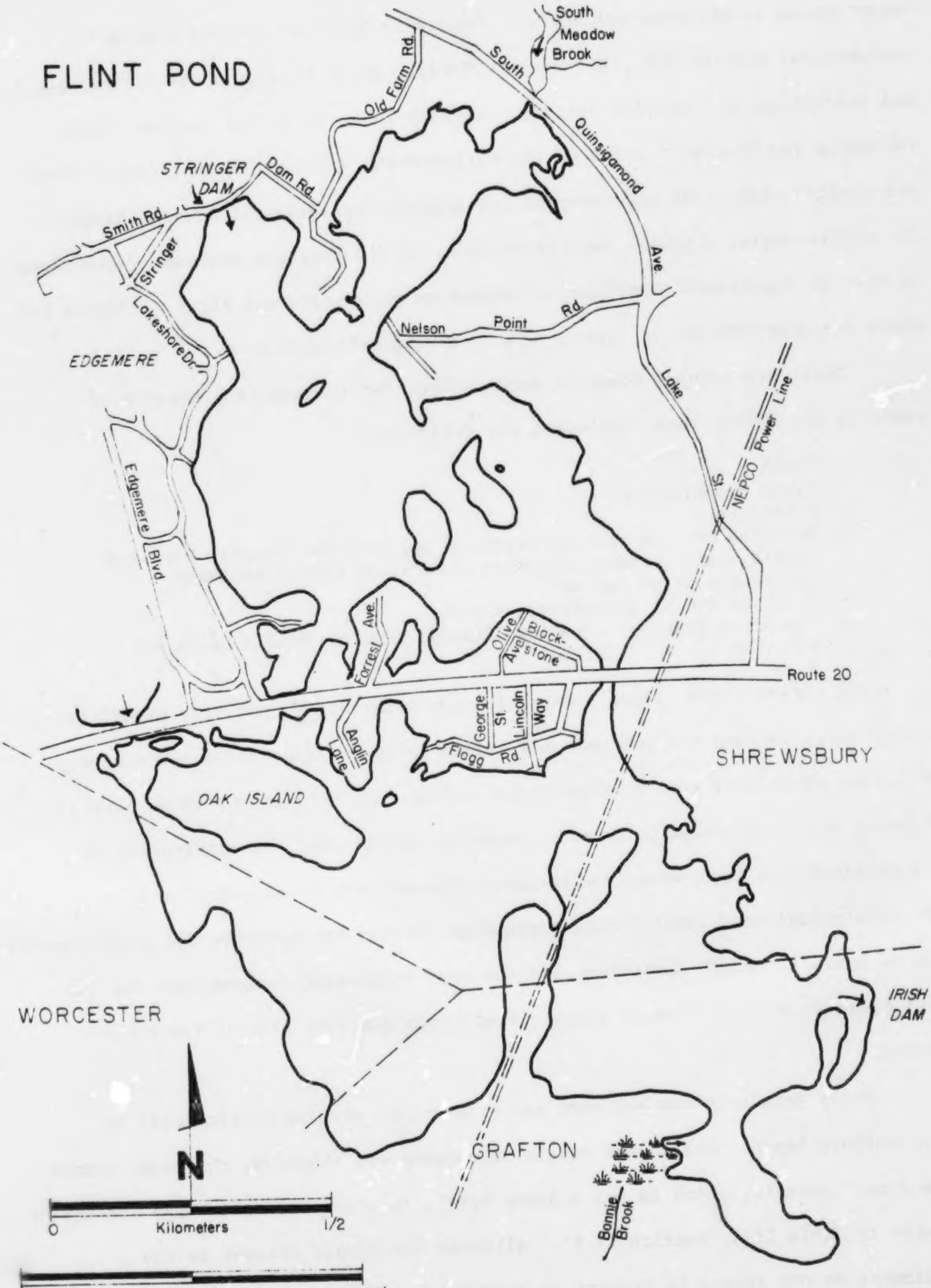

FLINT POND
South Meadow Brook
South Quinsigamond Ave.
Old Farm Rd.
Dam Rd.
STRINGER DAM
Smith Rd.
Stringer
Lakeshore Dr.
EDGEMERE
Nelson Point Rd.
Lake Ave.
NEPCO Power Line
Edgemere Blvd
Forrest Ave.
Olive Ave.
Blackstone
Route 20
George St.
Lincoln Way
Anglin Lane
Flagg Rd.
OAK ISLAND
SHREWSBURY
WORCESTER
IRISH DAM
GRAFTON
Bonnie Brook
N
0
Kilometers
1/2
0
1000'
2000'

FIGURE V-5

heavy metals in the pond sediments. Impacts on pond use include limits to recreational boating and other uses (swimming, water skiing, scuba diving, etc.), and reductions of fisheries habitat. Already 70 acres of the northern basin and nearly the entire 58 acres of the northern and southern basins, respectively are clogged with floating, submersed and emergent varieties of aquatic plants. The middle basin, although relatively clear of floating and emergent vegetation, is host to significant densities of submersed vegetation and algae. (Figure V-6 shows the distribution of aquatic plants throughout Flint Pond.)

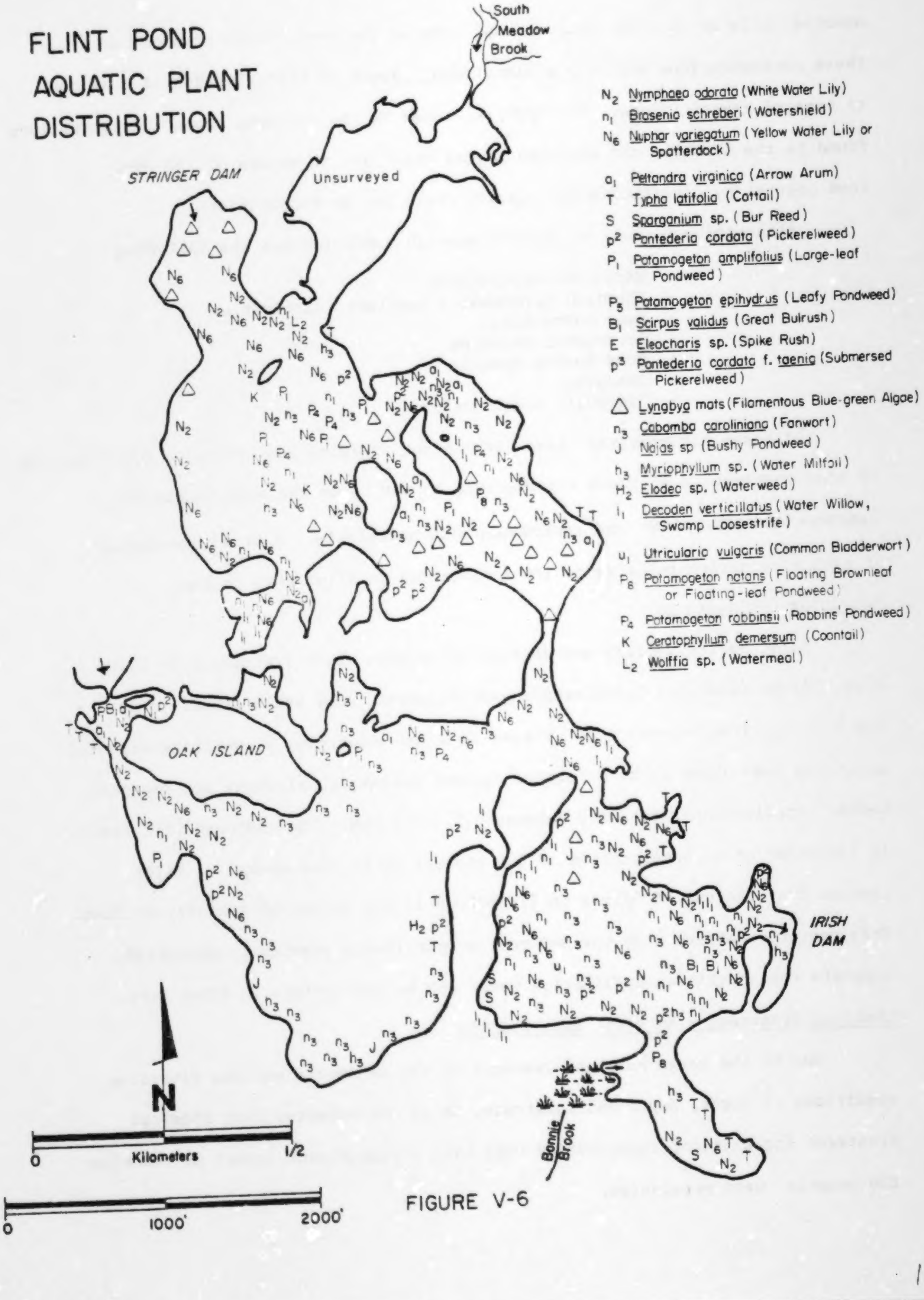
There are several possible explanations for the relative absence of weeds in the middle basin including the following:

- Depth
- Light Penetration
- Substrate
- Exchange of flow between northern and southern basins bypasses middle basin - hydraulic short-circuiting limits exchange and transport of matter
- Dilution due to groundwater inputs
- Weed-free exchange from Lake Quinsigamond to Middle basin via westerly Route 20 inflow

Of these, depth, light penetration and substrate do not vary significantly, particularly between the northern and middle basins. Based on water chemistry analysis, which indicates no significant differences between the three basins, dilution due to groundwater is not considered significant. A combination of the remaining reasons, weed-free exchange between Lake Quinsigamond and the middle basin and limited mixing/exchange between the northern and middle basins due to hydraulic short-circuiting, are the most reasonable explanations for the variations in distribution of aquatic weed types and densities in the three basins.

Heavy metals in the sediment are a potential problem particularly in the southern basin. Particular metals of concern are aluminum, chromium, copper and zinc. Arsenic, which is not a heavy metal, is also present in high concentrations. (Refer to Table II-4, section II-B). Although the metals present in the sediments do not appear to present an immediate problem either to fish or

FLINT POND AQUATIC PLANT DISTRIBUTION


South Meadow Brook
Unsurveyed
STRINGER DAM
OAK ISLAND
IRISH DAM
Bonnie Brook
N
0
Kilometers
1/2
0
1000'
2000'

N_2	Nymphaea odorata (White Water Lily)
n_1	Brasenia schreberi (Watersnield)
N_6	Nuphar variegatum (Yellow Water Lily or Spatterdock)
a_1	Peltandra virginica (Arrow Arum)
T	Typha latifolia (Cattail)
S	Sparganium sp. (Bur Reed)
p^2	Pontederia cordata (Pickerelweed)
P_1	Potamogeton amplifolius (Large-leaf Pondweed)
P_5	Potamogeton epihydrus (Leafy Pondweed)
B_1	Scirpus validus (Great Bulrush)
E	Eleocharis sp. (Spike Rush)
p^3	Pontederia cordata f. taenia (Submersed Pickerelweed)
△	Lyngbya mats (Filamentous Blue-green Algae)
n_3	Cabomba caroliniana (Fanwort)
J	Najas sp (Bushy Pondweed)
h_3	Myriophyllum sp. (Water Milfoil)
H_2	Elodea sp. (Waterweed)
I_1	Decoden verticillatus (Water Willow, Swamp Loosestrife)
u_1	Utricularia vulgaris (Common Bladderwort)
P_8	Potamogeton natans (Floating Brownleaf or Floating-leaf Pondweed)
P_4	Potamogeton robbinsii (Robbins' Pondweed)
K	Ceratophyllum demersum (Coontail)
L_2	Wolffia sp. (Watermeal)

FIGURE V-6

aquatic life or to limit recreational uses of the pond, their presence in these concentrations may have a significant impact on the selection of a method to control aquatic weeds. For example, based on the sediment copper concentrations found in the northern and southern basins which are in excess of 150 ppm, weed control by herbicide application could not be recommended.

Alternative methods to control aquatic weeds include the following:

- Herbicide application
- Chemical treatment - nutrient inactivation
- Weed harvesting
- Pond-level drawdown
- Pond bottom sealing
- Dredging
- Hydraulic modifications

Of these alternatives, weed harvesting, dredging and hydraulic modifications or some combination of these alternatives appear to be the most technically feasible and applicable and environmentally acceptable. A brief discussion of each alternative relative to its application in Flint Pond follows.

Herbicide Application

Based on the variety and density of aquatic weeds identified in Flint Pond, Silvex (2-(2,4,5-Trichlorophenoxy) Propionic Acid would appear to be the most applicable herbicide. Silvex is a non-selective, slow-acting compound which has been shown to be effective against submerged, floating and emergent weeds. Application rates vary between 0.5 - 2.0 ppm. The compound will remain in the water at a concentration of 1.0 ppm for up to five weeks. A major concern over the use of Silvex in Flint Pond is its potential toxicity to fish. This factor, combined with the sediment copper levels previously discussed, suggests that herbicide application would not be appropriate in Flint Pond.

Chemical Treatment - Nutrient Inactivation

Due to the large nutrient resevoir in the sediments and the favorable conditions of light, depth and substrate, it is not expected that chemical treatment for nutrient inactivation will have a significant impact on reducing the aquatic weed population.

Weed Harvesting

Although not considered a long-term solution in terms of its effectiveness, weed harvesting may be an effective method to reduce weed densities and recover impacted areas for recreational use on a short-term or temporary basis (Short-term and temporary generally ranging from 1 to 3 growing seasons.) Based on harvesting approximately 200 acres of the pond, the cost of weed harvesting would range from $20,000 to $65,000 based on $350/acre for harvesting by private contractor.

Pond Level Drawdown

Based on an assessment of the types of aquatic weeds found in Flint Pond and the success of this technique to control these species, drawdown would not be expected to have a significant impact in reducing aquatic weeds. Pond level drawdown may have to be considered in conjunction with the alternatives of pond bottom sealing, dredging or hydraulic modifications,but as a construction or operational technique rather than a weed control alternative.

Pond Bottom Sealing

Pond bottom sealing is not considered a feasible alternative for Flint Pond due to the need to dewater the pond, the effect of reducing the depth of the pond, disruption of the fisheries and the risk associated with the seal (of whatever type) being broken.

Dredging

In terms of a long-term control alternative, dredging to remove the volume of nutrients stored in the sediment, together with the heavy metals, is a technically feasible alternative. In addition to removing the sediments and weeds, dredging would increase the depth in critically clogged areas, such as the coves at the outlets of South Meadow and Bonnie Brooks, and the slack-water areas of the northern and southern basin. Disposal of dredged material and the time required to complete a project of this magnitude (two-three years) are major concerns with this alternative. Temporary impacts such as increased turbidity and release of nutrients and metals to the water column can be expected in the immediate work area of the dredging operation. A dredging program for Flint Pond could be targeted to the northern and southern basins. In the northern basin, an area of 70 acres to be dredged to a depth of two feet would yield 225,870 cubic yards of dredged material. Assuming an average cost of about $4/cubic yard for the dredging operation yields a cost of $903,480. Of the approximately 58 acres in the southern basin, 50 acres would be dredged to a depth of two feet yielding 161,330 cubic yards of dredged material. The 8-acre cove below Bonnie Brook involves a sediment depth of about six feet which would yield 77,440 cubic yards of material. The cost of dredging these areas would equal $645,320 and $309,760 respectively. The total cost for this dredging program would therefore equal $1,858,560.

Hydraulic Modifications

Modifying the hydraulic characteristics of the pond may be done to increase the flushing rate and the flow-through velocity or to improve water circulation in various portions of Flint Pond. Such modifications might serve to scour material from the water-sediment interface and/or prohibit or limit the amount of material allowed to settle within the pond. Hydraulic modifications might include the following:

- Changing the gate structures at Stringer Dam and Irish Dam from "overflow" weirs to "under-flow" type gates.
- Open a channel between the middle and southern basins at the southerly end of the peninsula separating the two basins.
- Open a channel through the small peninsula just above Irish Dam

Further evaluation of these alternatives is necessary. They may, however, have a significant impact on the long-term effectiveness of both land-based and in-lake control recommendations.

Recommendations

Based on the preceding discussions of various control options , technical feasibility, environmental impacts, and cost, the following control plan recommendations for Flint Pond are presented:

1. Weed harvesting should be performed on an "as-needed" basis with initial priority being given to the northern basin, followed by the southern basin followed by the middle basin. Although this is considered a temporary control, the cost of harvesting compared to dredging indicate that the pond could be harvested over 25 times for the same cost of dredging. The approach may be made more effective over the long term if recommendations regarding sewering and the control programs for South Meadow Brook and Bonnie Brook are implemented.

2. A study of the cove at the outlet of Bonnie Brook should be undertaken to determine if the cove can be recovered by dredging. If the cove cannot economically be recovered, it may be advisable to culvert Bonnie Brook directly into the southern basin and fill in the cove.

3. A study of hydraulic modification including those identified in the text should be undertaken. This study should also consider proposed modifications to Hovey Pond.

D. Tributary Watershed Management Plans

Poor Farm Brook

Segment 1 - Headwater to Clark Street

This segment of the watershed includes portions of West Boylston and Worcester. Recommended plan elements for the West Boylston portion of this segment include the following:

1. A septic system maintenance and inspection program and ordinance should be implemented including the specification of a minimum acceptable pumping frequency, for both industrial-commercial and residential systems;

2. Street sweeping activities should be increased during the early spring to remove sand and other substances accrued during the winter;

3. Drain clearing and stream maintenance activities should be conducted in spring and fall to remove sediment and leaves ;

4. Additional stream maintenance should be conducted along the utility right-of-way parallel to Shrewsbury Street to include removal of material accumulated behind fences crossing the brook and to effect streambank stabilization. A minimum 25-foot vegetated buffer zone should be maintained along this reach; and

5. Livestock at the Worcester County Jail Farm should be restricted from congregating at the brook near Shrewsbury Street and Briar Lane. An on-site detention basin or farm pond in a pasture area at the top of the hill might be constructed to accommodate the cattle.

Recommended plan elements for the portion of Segment 1 in the City of Worcester, which includes the stream reach from the West Boylston-Worcester line to Clark Street, include the following:

1. Streambank stabilization including a 25-foot vegetated buffer strip should be undertaken from East Mountain Street to Clark Street. Tree cover should be an integral part of the vegetation plan for the buffer strip;

2. Stripped and exposed slopes along the westerly side of the brook behind the Mountain Village and Quabbin Estates apartment developments should be covered and seeded to halt erosion problems. Terraces, runoff diversion berms and vegetative cover should be carefully designed and selected to prevent erosion and to blend into the buffer zone recommended in 1 above. Any proposed development of this area should include these considerations and recommendations in a site development plan;

3. The in-line detention basin located in the brook behind Quabbin Estates should be re-designed and constructed to serve as an integral element of the flood control and stormwater control plan for the watershed. Outlet design, storage capacity and bank stabilization should be included in a feasibility study; and

4. The Health Department should investigate the storm drainage systems at Gothic Avenue and Clark Street to identify any sources of bacterial pollution and, upon identification, take corrective action.

Segment 2 - Clark Street to Route 70

1. The 25-foot buffer strip initiated in Segment 1 should be extended along this segment;

2. Upon completion of the new Maplewood-Northwest Interceptor sewer projects, manholes and appurtenances of the original line should be removed from the brook channel and stream banks;

3. Stream bank stabilization measures should be taken along the stream from East Mountain Street up along the playground area abutting the Great Brook Valley project; and

4. Both Worcester and Shrewsbury should conduct sand collection and removal operations early in the spring along East Mountain and Clark Streets and the Northeast Cutoff respectively.

Segment 3 - Route 70 to Lake Quinsigamond

1. A plan should be developed to rehabilitate City Farm Pond for flood control and stormwater detention purposes. The plan should include consideration of providing a control gate at the outlet; dredging the pond to remove accumulated solids and eroded material; design of slope stabilization measures and erosion control measures along the southern and eastern shores of the pond;

2. Erosion control measures should be designed and implemented along the steep slopes south and east of the outlet of City Farm Pond ;

3. Stream cleaning should be conducted from the outlet of City Farm Pond to the Lake to remove tires, gas tanks, abandoned barrels and other litter and debris;

4. A 25-foot vegetated buffer strip should be maintained between the brook and the Goddard Industrial Park along the brook and the Lake;

5. A Stormwater drain discharging to the brook from the Jamesbury Corporation facility should be replaced with perforated pipe. Oil and sand trap catchbasins should be installed and maintained to prevent oil pollution from entering the brook through this system; and

6. The City of Worcester and the town of Shrewsbury should establish an aquifer protection district from the outlet of City Farm Pond to the Lake to protect primary drinking water supply wells located in this area. Limits to access and allowable/permissible uses of the land area within this district should be included in any rules and regulations issued pursuant to the establishment of the district.

In order to assist the implementation of recommended elements of the watershed management plan for Poor Farm Brook, it is further recommended that the City of Worcester and the towns of Shrewsbury and West Boylston jointly petition the Northeastern Worcester County Conservation District for the assistance of the Soil Conservation Service. This would be done to develop a comprehensive watershed management plan for Poor Farm Brook to include the design of erosion control measures; stream bank stabilization measures; detention basin at Quabbin Estates; rehabilitation of City Farm Pond and other related elements of the tributary management plan as appropriate.

Coal Mine Brook

Segment 1 - Source to Lincoln Plaza Drain

The high levels of coliform bacteria and nutrients found in this segment suggest a source of sewage contamination to the brook. An investigation by both the City of Worcester's Public Health Department and Department of Public Works of the storm drain system should be conducted in the Goldwaithe Road-Colby Avenue area and from LaSalle Avenue to Wellesley Avenue to locate any probable misconnections, cracked pipes, leaky joints, broken seals, etc.

Identified problems should then be corrected as soon as possible.

High chloride and solids levels indicate that an evaluation of highway deicing practices should be undertaken by the City of Worcester's Public Works Department and the Commonwealth of Massachusetts Highway Department to determine if sand and salt applications may be reduced in this area.

Segment 2 - Lincoln Plaza Drain to Plantation Street

Highway runoff from I-290 and soil erosion from the embankment behind the Lincoln Plaza Shopping Center contribute to the increased solids level found in this segment.

To prevent further erosion of this slope, perennial vegetation such as evergreens or shrubs should be established. In addition some structural measures may be required to reduce the quantity and velocity of runoff. Diversion berms and terraces are designed to reduce erosion by decreasing the slope gradient and promoting infiltration of runoff water. Terraces constructed of earth embankments are placed across the slope of the land. They consist of a level channel area and a ridge which together will act to reduce slope length and intercept the flow of surface runoff. A diversion berm or dike is a ridge of soil which acts to divert overland flow from eroding slopes.

Additional protection can be gained by the construction of a sedimentation basin equipped with a sand filter sub-drain at the Lincoln Plaza/I-290 culvert. This type of facility will serve to trap and detain sediment from the drainage area above.

Replacing the I-290 drainage culverts with a system such as a grassed waterway channel with a perforated pipe underdrain will reroute runoff to the groundwater for recharge. Erosion - resistant grasses or other vegetation should be established to protect the drainage channel. A perforated pipe underdrain constructed of corrugated steel along with crushed stone backfill will act to store the runoff until infiltration occurs. (Refer also to the section on I-290 in the Lake Quinsigamond section.)

A considerable amount of material has been discarded on the Notre Dame Institute property. This site should be cleaned and dumping in this manner should be prohibited as well as the burning that also occurs in this area.

Segment 3 - Plantation Street to Lake Quinsigamond

The relatively high concentration of bacteria and nutrients within this segment can be attributed to the storm drain system which originates on Lincoln Street and discharges to Lake Quinsigamond at the bridge abutment at Plantation Street. This system has been inspected and found to have leaks, misconnections, and broken pipes. The City of Worcester's Health Department and Public Works Department are in the process of correcting problems as they are identified.In order to protect a municipal water supply pumping station located at the mouth of the brook, consideration should be given to a relocation of this drain so that it discharges to the Lake at I-290. As in the section on I-290, it is recommended that the City of Worcester and the Massachusetts Department of Public Works enter into a cooperative agreement to address this problem.

Medical School Drain

During dry weather periods, the water quality at this location is relatively good. However, the monitoring data has indicated that solids and heavy metals, particularly lead and zinc, are introduced through stormwater runoff. Paved areas in this drainage system may be a major source of these pollutants. Contaminants from the operation of motor vehicles, the litter and debris which collects, and air borne particulates which settle out all accumulate on paved surfaces and are subsequently washed off by stormwater runoff. Source control measures are therefore necessary to alleviate the negative impact of runoff on water quality. A regular program of dry sweeping of the University of Massachusetts Medical School parking lot system as well as regular cleaning of the drainage system should be undertaken. In addition, the outfall and box culvert on North Access Road should receive regular inspection by the City of Worcester's Public Works Department and the Regatta Point Park Superintendent to determine the need for cleaning and other maintenance requirements.

It is further recommended that, under any plans to expand the extent of impermeable surface (by either parking lot or building expansion) the Medical School provide infiltration capacity for the first one-half inch of rain via perforated pipe drain systems, infiltration trenches, detention storage or other means.

Fitzgerald Brook

An investigation by the City of Worcestor's Public Health Department has revealed that a major source of the bacterial related pollution in Fitzgerald Brook was due to misconnections and broken or leaky sewer pipes. Misconnections were issued reconnection orders and maintenance problems were reported to the City Public Works Department for repair. Further monitoring by the Health Department will reveal the impact these measures have on water quality.

High levels of solids and seasonally high chloride levels indicate that an evaluation of street sweeping and deicing practices should be conducted by the Worcester Public Works Department in this area. Salt and sand applications on these residential streets might be reduced without sacrificing roadway driving safety and street sweeping might be conducted on a more frequent basis with special attention given to the removal of winter sand.

The Worcester Public Works Department should continue its brook channel maintenance and cleaning program. Particular areas in this drainage system that deserve attention include Cohasset Street and the section of brook from Coburn Avenue to Lake Quinsigamond. A considerable amount of debris, brush and leaves were found at these locations during the sampling program.
A preventative approach to halt the dumping of lawn trimmings, leaves and brush along stream channels can be taken by instituting a public awareness program

to inform residents that actions of this nature may clog stream channels and contribute to the degradation of water quality by the release of nutrients to the brook. A program during summer and fall to collect brush and leaves by the Public Works Department would also serve to alleviate this problem.

Modifications to the wetlands between Trahan and Ernest Avenues which serve as the headwaters of Fitzgerald Brook should be strictly regulated and monitored to prevent excessive sediment and nutrient loadings from entering the brook.

O'Hara Brook

For the most part, O'Hara Brook exhibits fairly good water quality. However, high levels of bacteria which occurred sporadically over the sampling period suggest a source of sewage contamination. To determine the cause, the storm drain system should be investigated for misconnections, broken pipes, etc., through the cooperative efforts of the Worcester Public Health Department and Public Works Department and corrected as soon as possible. Another possible source of sewage contamination may be surcharging septic systems. The implementation of a septic system inspection and maintenance program by the City's Public Health Department would serve to identify and eliminate contamination from sub-surface sewage disposal systems.

A small tributary which meets O'Hara Brook near Sunderland Road has its origins in the wetlands located in the Blithwood Avenue area. Extensive modifications to this site should be prohibited and the wetlands should be preserved as a wetlands district.

During wet periods high levels of solids, chloride and nitrogen predominate. It is recommended that the City of Worcester's Public Works Department review its deicing practices in this area to determine if a reduction in the use of sand and salt would be feasible.

A good deal of leaves, grass and brush are dumped on the banks of this stream. Activities of this nature should be prohibited because of the amount of nutrients that will be contributed to the brook. A public awareness program conducted by the Worcester Conservation Commission to educate people as to the detrimental effects these actions have on water quality would be beneficial as would special collections of leaves and brush by the Public Works Department during critical seasons.

Newton Pond

Analysis of the monitoring data reveals that, with the exception of occasional dissolved oxygen violations, the Newton Pond drainage area meets the Class B water quality criteria.

In order to preserve this class of water, consideration should focus on preventative source control measures. One recommendation is to maintain the land surrounding Newton Pond, which is sparsely developed, in private ownership with certain restrictions placed upon the land. In this manner, activities which would be detrimental to water quality such as, dumping, removal of vegetation, excavation and development would be prohibited.

The wetlands situated in the northern portion of this drainage area serve in an efficient filtering and settling capacity for pollulants and should be retained in their natural state as wetland districts.

It is recommended that at least a 25-foot buffer strip should be maintained around the gravel pit owned by the Worcester Sand and Gravel Company to take advantage of the filtration and purification functions of the land.

Billings Brook

Segment 1 - Source to Main Street

There are no major pollution problems in the relatively small drainage basin of Billings Brook. Water quality generally meets the Class B criteria with the exception of occasional dissolved oxygen violations. To maintain or improve this situation, emphasis should be placed on preventative and corrective measures.

The Slocum Meadow marsh situated between Route I-290 and Main Street serves at the headwaters of Billings Brook. It provides a habitat for wildlife, acts as a flood control mechanism, and removes nutrients and other pollutants. As such this environmentally sensitive area should be retained in its natural state as a wetlands district.

Segment 2 - Main Street to Lake Quinsigamond

A small wetland which can be found upstream of Quinsigamond Avenue should also be maintained since it serves an important function in this gravel mining area of trapping sediment prior to the Brook's discharge to Lake Quinsigamond at Eagle Head Cove.

A sedimentation basin near the F & G Sand and Gravel Company should continue to be maintained in order to curtail erosion and downstream siltation from mining operations.

A regular inspection of the lagoon found above the culvert at Quinsigamond Avenue should be undertaken by the Town of Shrewsbury's Water and Sewer Department and cleaning performed if necessary.

Tilly Brook

Segment 1 - Source to Mill Pond

The water quality in this segment of Tilly Brook is generally good. However, a distinct rise in phosphorus concentrations was observed during the March monitoring period which might be indicative of spring fertilizer applications. To eliminate this type of pollution, a public information program might be designed by the Shrewsbury Conservation Commission to inform residents of the harmful effects of overfertilization as well as providing instruction on the proper usage, application and storage of fertilizers.

An extensive upland wetland, the Slocum Meadow marsh, through which the brook flows serves many beneficial functions including filtration, purification, wildlife habitat and flood storage. To take full advantage of these valuable natural functions, this ecologically sensitive area should be retained as a wetlands district.

Segment 2 - Mill Pond to Culvert at Spag's

The Town of Shrewsbury is currently employing the technique of lowering the water level to control the dense growths of macrophytes which have become a problem in Mill Pond. An evaluation of the effectiveness of this technique will determine the need for further action.

A program to monitor the brook should be conducted by the Shrewsbury Board of Health in order to determine the impact of connecting a large capacity septic system at the Worcester Foundation for Experimental Biology to the sewer system. If any subsequent problems exist, they may be more clearly identified and corrected.

Segment 3 - Culvert at Spag's to Lake Quinsigamond

Unacceptably high concentrations of coliform bacteria indicate possible sewage contamination in this segment. To determine the source or sources, an investigation of the culvert should be undertaken jointly by the Town of Shrewsbury's Board of Health and the Sewer and Water Department. A program of both visual and televised inspection in addition to dye tracer testing would serve this purpose. Corrective action should then be initiated on any identified problems.

The many roads, commercial/industrial parking lots and other paved areas throughout this segment deserve particular attention to reduce the loadings of solids, nutrients and metals to the brook. Many of these contaminants are contributed by the accumulation on paved surfaces of trash, dustfall and debris from cars and trucks. A program of regular dry-sweeping of the numerous industrial/commercial lots should be instituted and the washing down of paved areas should be prohibited. Route 9 and Quinsigamond Avenue with its many commercial areas would benefit from an intensified street sweeping program by the Town of Shrewsbury's Highway Department. Two consecutive cleaning cycles would serve to increase the effectiveness of street sweeping .

The Harvey Place pumping station should continue to be regularly inspected by the Sewer and Water Department for leaks, broken seals and other malfunctions because of its close proximity to a major recreational area on the Lake as well as for the protection of residents in the area.

Jordan Pond

Monitoring of the bacterial water quality suggests a source of sewage contamination possibly from either the sewer system or septic tanks. The sewer system should be investigated by the Town of Shrewsbury's Sewer and Water Department, for leaks, misconnections or connections that were never made. Corrective action should then be taken. A septic system maintenance and inspection program operated by the Board of Health would aid in identifying system failures and eliminating contamination from subsurface disposal systems. Similarly, the Jordan Pond pumping station should be regularly inspected by the Sewer and Water Department for leaks, broken seals, or other system failures.

A street sweeping program with special emphasis placed on the Route 9-Edgewater Avenue area would act to combat solids loadings in this drainage area.

Jordan Pond tends to act in much the same manner as a detention basin for Lake Quinsigamond. Sediment and other pollutants are allowed to settle out. Since this is such an active recreational area for both contact and non-contact activities, Jordan Pond should be further evaluated to determine what impacts stormwater exerts on it.

South Meadow Brook

Segment 1 - Source to Route 9

Seasonally high levels of chloride indicate that the Town of Shrewsbury's Highway Department should evaluate its deicing program to determine if sand and salt applications might be reduced on these primarily residential streets.

Segment 2 - Route 9 to Flint Pond

South Meadow Brook originates in a small upland wetland and much of the drainage area of this brook is dominated by a wetland known as Peat Meadow. Since wetlands perform a natural filtering function by acting as a trap for sediment and other suspended material, they are an excellent control mechanism to prevent these substances from entering the Lake. Measures should be taken to maintain these areas in their natural state as wetland districts.

With the exception of one sampling date, water quality generally meets the Class B criteria. To preserve this quality of water it is strongly recommended that a mandatory septic system inspection and maintenance program be instituted by the Town of Shrewsbury's Board of Health as a preventative measure.

In addition to a 400 foot buffer zone established around the Oak Street well, care should be taken within the aquifer recharge area to assure that groundwater supplies are recharged by infiltration and are safeguarded from contamination. Minimum lot sizes, regulation of the amount of impervious surface and regulation over the use and storage of potential contaminants are examples of techniques which may be utilized to protect groundwater supplies.

Bonnie Brook

With the removal of stormwater flows and waste treatment discharges from the brook by the Wyman-Gordan Company, the major problem to be addressed in this brook is the quantity and chemical nature of the brook channel sediments. These sediments have been shown to contain high concentrations of heavy metals and have also resulted in severely clogging an eight-acre cove at the southern end of the southern basin of Flint Pond. This cove is nearly filled in and is completely clogged with dense growths of aquatic vegetation.

There are basically two approaches available to overcome the present situation. The first approach would involve dredging the brook channel from Wyman-Gordan to the cove, stabilize the channel and coordinate channel rehabilitation with the rehabilitation of the cove. The alternative approach would involve culverting the brook from Wyman-Gordan directly to the southern basin, by-passing both the cove and the existing channel. The selection of one alternative over the other can not be made until a final decision is reached regarding the implementation of control/rehabilitation measures for Flint Pond. It is imperative to recognize the importance of the flow contribution of Bonnie Brook to Flint Pond. Bonnie Brook contributes nearly 18 per cent of the total flow to the pond. As such, decisions regarding the brook can have a significant impact on the water budget for the pond. It is recommended that Bonnie Brook be included in the study previously recommended for the cove area of the southern basin of Flint Pond in the management plan section for Flint Pond.

REFERENCES

American Public Works Association, *Report on Problems of Combined Sewer Facilities and Overflows*, Federal Water Pollution Control Administration, December 1967.

American Society of Civil Engineers, *Nomographs for Ten-Minute Unit Hydrographs for Small Urban Watersheds*, Technical Memorandum No. 32, Urban Water Resources Research Program, December 1977.

American Society of Civil Engineers, *Sedimentation Engineering, Manual on Engineering Practice No. 54*, Vito A. Vanoni editor, New York 1975.

American Society of Civil Engineers, *Watershed Management*, Symposium conducted by the Committee on Watershed Management of the Irrigation and Drainage Division of the ASCE, 1975.

American Society of Civil Engineers and Water Pollution Control Federation, *Design and Construction of Sanitary and Storm Sewers*, 1969.

American Society for Testing and Materials, *Biological Methods For The Assessment of Water Quality*, ASTM Special Technical Publication 528, 1973.

American Society for Testing and Materials, *Manual on Water*, 1969.

The American Water Works Association, *Water Quality and Treatment*, McGraw Hill Book Company, 1971.

Athayde, Dennis N., *The Urban Stormwater Runoff Presentation*, 208 Seminar, Spring 1977, Reston, VA.

Baldwin, John L., *Climates of the United States*, U.S. Deptartment of Commerce, 1974.

Barbour, M.G., Burk, J.H., and Pitts, W.D., *Terrestrial Plant Ecology*, Benjamin/Cummings Publishing Co., Menola Park, CA, (1980).

Bartleson,Gilbert Carl, *The Chemical Investigation of Recent Lake Sediments from Wisconsin Lakes and Their Interpretation*, prepared for U.S. Environmental Protection Agency, University of Wisconsin, March, 1971.

Bartos, Michael J. Jr., *Classification and Engineering Properties of Dredged Material*. Tech. Rep. D-77-18,September 1977.

Baystate Environmental Consultants, Inc., *City of Westfield Evaluation of Aquatic Weed Harvesting Demonstration on Horse Pond*, June 1978.

Baystate Environmental Consultants, Inc. and Purcell Associates, *Springfield Lakes and Ponds Inventory and Restoration Plan*, Presented to City of Springfield Park Commissioners, May 1980.

Burks, S.A. and Engler, P.M., *Water Quality Impacts of Aquatic Dredged Material Disposal* (Laboratory Investigations), Tech. Rep. DS-78-4, August 1978.

Bursztymsky, Taras A. et al, *Treatment of Combined Sewer Overflows by Dissolved Air Flotation*, EPA-600/2-75-033,September 1975.

Beichly, G.L., *Hydraulic Design of Stilling Basin for Pipe or Channel Outlets*, Research Report No. 24, U.S. Bureau of Reclamation, 1971.

Bennett, George W., *Management of Lakes and Ponds*, Von Nostrand Reinhold Company, 1970.

Berger, Bernard B., Kusler, Jon A., Klinginer, Sally, *Lake-Shoreland Management Programs: Selected Papers*, Water Resources Research Center, University of Massachusetts, February 1976.

Betson, Roger, *Urban Hydrology - A Systems Study in Knoxville, Tennessee*, Tennessee Valley Authority, Division of Water Management, June 1976.

Brannon, J.M., *Evaluation of Dredged Material Pollution Potential*, Tech. Rep. DS-78-6, August 1978.

Brannon, J.M., Plumb, R.H., and Smith, Isaac, *Long-Term Release of Contaminants from Dredged Material*, Tech.Rep. D-78-49, August 1978.

Brater, Ernest F. and Sherrill, James D., *Rainfall-Runoff Relations on Urban and Rural Areas*, EPA-670/2-75-046, May 1975.

Bregman, Jacob I., and Gehm, Harry W., *Handbook of Water Resources and Pollution Control*, Van Nostrand Reinhold Company, New York, N.Y.,(1976).

Brenner, Robert; Moshman, Jack, *Benefits and Costs in the Use of Salt to Deice Highways*, The Institute for Safety Analysis, November 1976.

Carr, Jerome B., *Integrated Iron and Nitrogen Control for Lake Restoration*, U.S. Environmental Protection Agency, Massachusetts Division of Water Pollution Control, Wellesley Department of Public Works, November 1979.

Cullinan Engineering Co., Inc., *Feasibility Study for Rehabilitation of Hovey Pond Grafton, Massachusetts*, Prepared for Commonwealth of Massachusetts, Department of Environmental Quality Engineering, Division of Waterways, August 1979.

Culp, Russell L., Wesner, George Mack, Culp, Gordon L., *Handbook of Advanced Wastewater Treatment*, Van Nostrand Reinhold Company, 1978.

Curran, Timothy M. and Wanielista, Martin P., *SMADA - Stormwater Management and Design Aid*, American Society of Civil Engineers Preprint 80-603, October, 1980.

Dalrymple, Robert J. et al, *Physical and Settling Characteristics of Particulates in Storm and Sanitary Wastewaters,* EPA-670/2-75-011, April 1975.

Dawdy, David R., *Preliminary Documentation - Dawdy-Schaake Urban Runoff Model*, U.S. Geological Survey, Bay St. Louis, Mississippi, March 1977.

Dean, Lillian F., *A Description and Assessment of Stormwater Management Programs in Oakland County*, Southeast Michigan Council of Governments, March 1981.

Dean, Lillian F., *Effective Stormwater Management Programs: Case Studies of Local Government Experiences in Southeast Michigan*, Southeast Michigan Council of Governments, March 1981.

Dean, Lillian F., Management Options of Implementing Stormwater Quality Controls in Southeast Michigan, Southeast Michigan Council of Governments, September 1981.

Department of Water Resources, State of Maryland, Guidelines for Erosion and Sediment Control Planning and Implementation., EPA-R2-72-015, August 1972.

Donigian, Jr., Anthony S., Crawford, Norman H., Modeling Nonpoint Pollution from the Land Surface, EPA-600/3-76-083, July 1976.

Eckenfelder, W. Wesley, Jr., Principles of Water Quality Management, CBI Publishing Company, Inc., 1980.

Eckert, J.W., Giles, M.L. and Smith, G.M., Design Concepts for In-Water Containment Structures for Marsh Habitat Development, Tech. Rep. D-78-31, July 1978.

Environmental Design and Planning, Inc., Alternatives For Stormwater Pollution Control Lake Quinsigamond Urban Runoff Project Appendix submitted to Massachusetts Department of Environmental Quality Engineering, May 1981.

Environmental Design and Planning, Inc., Report on Stormwater Measurements and Modeling Lake Quinsigamond Urban Runoff Project Appendices A,B and C for Department of Environmental Quality Engineering, April 1981.

Environmental Design and Planning, Inc., Report on Stormwater Measurements And Modeling Lake Quinsigamond Urban Runoff Project Appendices D,E and F For Department of Environmental Quality Engineering, April 1981.

Environmental Design and Planning,Inc.,and META Systems,Inc.,Interim Report Engineering Services in Lake Quinsigamond Urban Runoff Project, Submitted to Massachusetts Department of Environmental Quality Engineering,September 1980.

Fassett, Norman C., A Manual of Aquatic Plants, The University of Wisconsin Press, 1969.

Feng, Tsuan H., Control Of Benthic Deposits in Lakes, Water Resource Research Center, University of Massachusetts at Amherst, July 1971.

Field, Richard and Lager,John A., Counter Measures For Pollution From Overflows - The State of the Art, EPA-670/2-74-090, December 1974.

Field, Richard, Tafuri, Anthony N., Masters, Hugh E., Urban Runoff Pollution Control Technology Overview, Municipal Environmental Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, March 1977.

Fraser, F. Jean, Savilonis, Brian, Papadakis, John, Thomas, Richard, Lake Quinsigamond A Study of Water Quality Management, New England Board of Higher Education, Student Internships In Economic Development Programs, 1971.

Gehm, Harry W. and Bregman, Jacob I., Handbook of Water Resources and Pollution Control, Van Nostrand Reinhold Company, 1976.

Gibson, M., Ramsey, R.H., Claburn, B.J., Sweazy, R.M., Wells, D.M., Variation of Urban Runoff Quality and Quantity with Duration and Intensity of Storms, Phase III, Volumes I-IV, NTIS, December 1975.

Government Finance Research Center, Financial and Institutional Considerations in Water Quality Planning : Case Studies 1979-1980 (Draft), Financial Management Assistance Program, May 1980.

Government Finance Research Center, Integrating Financial Analysis into the Wasteload Allocation Process (Draft), Financial Management Assistance Program, May 1980.

Government Finance Reasearch Center, Planning for Clean Water Programs: The Role of Financial Analysis, Financial Management Assistance Program, 1981.

Government Finance Research Center, Planning for Urban Stormwater Management: Financial Issues and Options (Draft), Financial Management Assistance Program, May 1980.

Government Finance Research Center, Regional Wastewater Treatment Systems: The Role of Cost Sharing (Draft), Financial Management Assistance Program, May 1980.

Government Finance Research Center, Sewer Extension as Spetic System Relief Projects: Principles to Encourage Cost-effective Solutions (Draft), Financial Management Assistance Program, May 1980.

Government Finance Research Center, Small Community Wastewater Systems: Financial Guidelines for Planning and Management (Draft), Financial Management Assistance Program, May 1980.

Government Finance Research Center, The Wastewater Construction Grants Program: Financial Issues for Small Communities (Draft), Financial Management Assistance Program, May 1980.

Government Finance Research Center, Wastewater Treatment Systems: A User's Guide to Feasibility Analysis of Conventional and Alternative Systems (Draft), Financial Management Assistance Program, May 1980.

Habitat School for Environment, De-icing Salts and the Environment, February 1972.

Harper, Harvey H., Cassagnol, Claude L. and Wanielista, Martin P., Detention/ Retention Stormwater Designs, American Society of Civil Engineers Preprint 80-599, October 1980.

Hayden, M.C., Prediction of Volumetric Requirements for Dredged Material Containment Areas, Tech. Rep. D-78-41, August 1978.

Hayes, Seay, Mattern and Mattern, Engineering Investigation of Sewer Overflow Problem, Federal Water Quality Administration, 11024DMS05/76, May 1970.

Heaney, James P., Huber, Wayne C., Nix, Stephen J., Storm Water Management Model - Level 2-Preliminary Screening Procedures, EPA-600/2-76-275, October 1976.

Heaney, James P., et al., Nationwide Evaluation of Combined Sewer Overflows and Urban Stormwater Discharges, Volume II: Cost Assessment and Impacts, EPA-600/2-77-064, March 1977.

Heaney, James P., et al., Storm Water Management Model: Level I - Comparative Evaluation of Storage-Treatment and Other Management Practicee, Draft Report, 1977.

Hill, David E. and Frink, Charles R., Longevity of Septic Systems in Connecticut Soils, Connecticut Agricultural Experiment Station, June 1974.

Hirsch, N.D., DiSalvo, L.H. and Reddicord R., Effects of Dredging and Disposal on Aquatic Organisms, Tech. Rep. DS-78-5, August 1978.

Huber, Wayne C. and Heaney, James P., Urban Rainfall-Runoff-Quality Data Base, EPA-600/8-77-009, July 1977.

Huber, Wayne C. and Heaney, James P. et al, Stormwater Management Model User's Manual, Version II, EPA-670/2-75-046, May 1975.

Isaac, Russell and Delaney, John, Trace Element Survey in Massachusetts, Publication No. 9817-18-75-6-77-CR, Massachusetts Department of Environmental Quality Engineering, Division of Water Pollution Control.

Jenkins, Dale W., Biological Monitoring of Toxic Trace Elements, EPA-600/53-80-090, February 1981.

Johnson, David E., Storm Drainage And The Building Community, American Society of Civil Engineers Preprint 80-512, October 1980.

Koerner, Robert M. and Welsh, Joseph P., Construction and Geotechnical Engineering Using Synthetic Fabrics, John Wiley and Sons, 1980.

Kuzminski, Lawrence N. and Grier, James, Heavy Metals In The Water And Sediment of Lakes In Western Massachusetts-II. Copper, Progress Report for the Massachusetts Division of Water Pollution Control, University of Massachusetts, January 1974.

Kuzminski, Lawrence N. and Hogan, William, Heavy Metals In The Water and Sediment of Lakes in Western Massachusetts - III. Lead, Progress Report for the Massachusetts Division of Water Pollution Control, University of Massachusetts, January 1974.

Kuzminski, Lawrence N. and Stine, Gibson, Heavy Metals in the Water and Sediment of Lakes in Western Massachusetts - I. Arsenic, Progress Report for the Massachusetts Division of Water Pollution Control, University of Massachusetts, November 1973.

Lager, John A. and Smith, William G. - Metcalf and Eddy, Inc., Urban Stormwater Management and Technology - An Assessment, EPA - 670/2-74-040, December 1974.

Linsley, Ray K. and Franzin, Joseph B., Water-Resources Engineering, McGraw-Hill Book Company, 1972.

Arthur D. Little, Inc., A Systems Evaluation of Alternative Statewide Resource Recovery Techniques for the Disposal of Municipal Solid Waste, Report to Massachusetts Department of Public Works, December 1973.

Lower Pioneer Valley Regional Planning Commission, Interim Water Quality ManagementPlan forThe Lower Pioneer Valley, September 1979.

C.E. Maguire, Inc., Hydrology and Hydraulics Studies, Blackstone River Basin, 1976.

Mallory, C.W., The Beneficial Use of Stormwater, EPA-R2-73-139, January 1983.

Manhattan College, Basic Models of Natural Water Systems, Prepared for U.S. Environmental Protection Agency.

Massachusetts Department of Environmental Management and U.S. Environmental Protection Agency, Resource Recovery The Clean Route From Waste To Energy A Proposal For Worcester and Central Massachusetts.

Massachusetts Division of Water Pollution Control, The Blackstone River Tributaries Water Quality Data - 1977, July 1978.

Massachusetts Division of Water Pollution Control, Septic Systems and Your Lake.

Massachusetts Water Resources Commission, Lake Quinsigamond Study 1971 Water Quality Data Appendix A, Water Quality Section, Division of Water Pollution Control, March 1972.

McElroy, A.D. et al., Loading Functions for Assessment of Water Pollution from Nonpoint Sources, EPA-600/2-76-151, May 1976.

McGinn, Joseph M., Analysis of Urban Stormwater Runoff and Combined Sewer Overflows in the Boston Metropolitan Area, Metropolitan Area Planning Council, 1978.

McLean, M.P., McNichol, R.E. and Scherer, E., Bibliography of Toxicity Test Methods for the Aquatic Enviroment, No. 50, 1980.

McPherson, M.B., Urban Runoff Control Planning, ASCE Urban Water Resources Research Council, June 1977.

Metcalf and Eddy, Inc., University of Florida, Water Resources Engineers, Inc., Stormwater Management Model, Volumes I-IV, EPA, 11024DOC07/71,July 1971.

Metcalf and Eddy, Inc., Wastewater Engineering; Collection, Treatment, Disposal, McGraw-Hill, New York, 1972.

Metropolitan Area Planning Council, Nonzoning Land-Use Protection Techniques, December 1978.

Metropolitan Area Planning Council, North Coastal Basin Preliminary Report, Water Quality Project, August 1977.

Metropolitan Area Planning Council, Summary of Data Analyses on Sediments and Benthic Invertebrates from the Ipswich, Charles, Assabet, Sudbury and Neponset Rivers, September 1977.

Metropolitan Area Planning Council, Water Resources Protection Techniques, October 1978.

Miller, Clayton R., Viessman, Jr. Warren, Runoff Volumes from Small Urban Watersheds, Water Resources Research, Vol. 8, No. 2, April, 1972.

Mitchell, Ralph, Introduction to Environmental Microbiology, Prentice-Hall, Inc., 1974.

Montachusett Regional Planning Commission, Report on Institutional Alternatives for Septic Tank Operation and Maintenance Programs and Septage Management in the Montachusett Region (Draft), May 1977.

Morgan, James J., and Stumm, Werner, Aquatic Chemistry, John Wiley and Sons, Inc., 1970.

Mugford, Paul S., Illustrated Manual of Massachusetts Freshwater Fishes, Massachusetts Division of Fisheries and Game, 1969.

Namminga, H. and Wilhm, J., Heavy Metals in Water, Sediments, and Chironomids, Journal-Water Pollution Control Federation, July 1977.

National Association of Conservation Districts, Report on State Sediment Control Institutes Program, EPA-440/9-75-001, April 1975.

New England Research, Inc., Draft Environmental Impact Report Control of Aquatic Vegetation in the Commonwealth of Massachusetts, Department of Environmental Quality Engineering, Metropolitan District Commission, Department of Environmental Management, November 1977.

Northeast Illinois Natural Resource Service Center, Standards and Specifications for Soil Erosion and Sediment Control in Northeastern Illinois, ISBN 0-88417-001-2, August 1973.

Northeast Illinois Natural Resource Service Center, Northeastern Illinois Planning Commission, Soil and Water Conservation Districts and Soil Conservation Service, USDA, Standards and Specifications for Soil Erosion and Sediment Control, August 1973.

Nriagu, Jerome O., Environmental Biogeochemistry, Vol.1 and Vol.II, Ann Arbor Science, Ann Arbor, Michigan, (1976).

Odum, Eugene P., Fundamentals of Ecology, W.B. Saunders Company, (1971).

Owen, Oliver S., Natural Resource Conservation: An Ecological Approach, Macmillan Publishing Company, Inc., 1975.

Pisano, William C. and Rhodes, John, Alternatives for Stormwater Pollution Control Lake Quinsigamond Urban Runoff Project, Environmental Design and Planning, Inc. for Massachusetts Department of Environmental Quality Engineering, May 1981.

Pisano, William C. and Rhodes, John A., Report on Measurements/Modelling Lake Quinsigamond Urban Runoff Project, Environmental Design and Planning, Inc., for Massachusetts Department of Environmental Quality Engineering, April 1981.

Plotkin, Stephen and Ram, Neil M., Establishment of an Algal Assay Laboratory, Progress Report to the Massachusetts Division of Water Pollution Control, Environmental Engineering Program, Department of Civil Engineering, University of Massachusetts/Amherst, January 1982.

Purcell Associates, Application of Dredging and Weed Harvesting-Bantam Lake, Morris and Litchfield, CT, Prepared for Connecticut Department of Environmental Protection, June 1978.

Reid, George K. and Wood, Richard D., Ecology of Inland Waters and Estuaries, D. Van Nostrand Company, 1976.

Ricklefs, Robert E., The Economy of Nature, Chiron Press, 1976.

Roy, Steven P., Road Salts and Water Supplies Best Management Practices, Office of Planning and Program Management, Department of Environmental Quality Engineering, August 1981.

Rubin, Alan J., Aqueous-Environmental Chemistry of Metals, Ann Arbor Science, Michigan, 1976.

Salo, John E. and Cooperman, Alan N., Lake Quinsigamond Water Quality Study 1971, Water Resources Commission, Water Quality Section, Division of Water Pollution Control, April 1972.

Sartor, James D. and Boyd, Gail B., Water Pollution Aspects of Street Surface Containinants, EPA-R2-72-081, November 1972.

Sawyer, Clain N., and McCarty, Perry L., Chemistry for Sanitary Engineers, 2nd Edition, McGraw-Hill, 1967.

Shelley, Philip E., Monitoring Requirements, Methods, and Costs For the Nationwide Urban Runoff Program, Water Planning Division, U.S. Environmental Protection Agency, October 1979.

Shelley, Philip E., Parameter Handbook For The Nationwide Urban Runoff Program, Water Planning Division, U.S. Environmental Protection Agency, October, 1979.

Sherer, E., Toxicity Tests for Freshwater Organisms, Dept. of Fisheries and Oceans Freshwater Institutions.

Southeast Michigan Council of Governments, Detention Basin Maintenance: Program Needs and Financing Options, Technical Bulletin No. 3, May 1981.

Southeast Michigan Council of Governments, Performance Zoning: An Innovative Approach to Water Quality Protection and Land Use Regulation, Technical Bulletin No. 7, July 1981.

Southeast Michigan Council of Governments, Protecting Water Quality Through Cluster Development: Financial Incentives and Community Benefits, Technical Bulletin No. 5, May 1981.

Southeast Michigan Council of Governments, Stormwater Management Planning: Cost-Saving Methods for Program Development, Technical Bulletin No. 1, June 1981.

Southeast Michigan Council of Governments, Stormwater Runoff Control Through Natural Drainage: Cost Savings and Environmental Benefits, Technical Bulletin No. 2, May 1981.

Southeast Michigan Council of Governments, Water Quality Guidelines for Development Plan Reviews: A Handbook for Local Officials in Southeast Michigan, October 1980.

Stall, John B and Terstriep, Michael L., Storm Sewer Design - An Evaluation of the RRL Method, EPA-R2-72-068, October 1972.

Stanley Consultants, Preventive and Corrective Measures for Controlling Agricultural Pollution, Staff Paper No. 26, Northeastern Illinois Planning Commission, September 1977.

Taylor J.S., Godlewski, V., Moore, P. and Snyder, B.A., Coagulation and Detention of Stormwater Runoff, American Society of Civil Engineers Preprint 80-666, October 1980.

Thelen, Edmund et al, Investigation of Porous Pavements for Urban Runoff Control, 11034 Duy 03/72, March 1972.

Thronson, Robert E., Best Management Practices Guidance, Discharge of Dredged or Fill Materials, U.S. Environmental Protection Agency, Office of Water Planning and Standards, Water Planning Division, September 1979.

Thronson, Robert E., Nonpoint Source Control Guidance, Agricultural Activities, U.S. Environmental Protection Agency, Office of Water Planning and Standards, Water Planning Division, February 1978.

Thronson, Robert E., Nonpoint Source Control Guidance - Construction Activities, December 1976.

Tourbier, Joachim and Westmacott, Richard, Water Resources Protection Measures in Land Development - A Handbook, Water Resources Center, University of Delware, April 1974.

U.S. Department of Agriculture, Engineering Field Manual, Soil Conservation Service, April 1975.

U.S. Department of Agriculture- Soil Conservation Service - Guidlines for Soil and Water Conservation in Urbanizing Areas of Massachusetts, Amherst Massachusetts, October 1975.

U.S. Department of the Interior, Design of Small Dams, Bureau of Reclamation, 1977.

U.S. Department of the Interior, Groundwater Manual, Bureau of Reclamation, 1977.

U.S. Department of the Interior, Office of Water Data Coordination, Geological Survey, National Handbook of Recommended Methods for Water-Data Acquisition, 1977.

U.S. Department of Transportation Design Charts for Open Channel Flow, Hydraulic Design Series No. 3, May 1973.

U.S. Department of Transportation, Design of Roadside Drainage Channels, Hydraulic Design Series No. 4, December 1973.

U.S. Department of Transportation, Drainage of Highway Pavement, Hydraulic Engineering Circular No. 12, March 1969.

U.S. Environmental Protection Agency, Areawide Assessment Procedures Manual, Volumes I-III, EPA-600/9-76-014, July 1976.

U.S. Environmental Protection Agency, Clean Lakes Program Guidance Manual (Final Draft),Office of Water Regulation and Standards, Criteria and Standards Division, September 1980.

U.S. Environmental Protection Agency, Combined Sewer Overflow Seminar Papers, EPA-670/2-73-077, November, 1973.

U.S. Environmental Protection Agency, Cost Estimates for Construction of Publicly Owned Wastewater Treatment Facilities - Summaries of Technical Data For Combined Sewer Overflows and Stormwater Discharges - 1976 Needs Survey, MCD-48C, EPA-430/9-76-012, February 10, 1977.

U.S. Environmental Protection Agency, Final Draft Preliminary Results of the Nationwide Urban Runoff Program, Volume II-Appendices, Water Planning Division, January 1982.

U.S. Environmental Protection Agency, Guidlines for the Pollutional Classification of Great Lakes Harbor Sediments, Region V, Chicago, April, 1977.

U.S. Environmental Protection Agency, Manual for Deicing Chemicals: Application Practices, EPA670/2-74-045, December 1974.

U.S. Environmental Protection Agency, Manual for Deicing Chemicals: Storage and Handling, EPA-670/2-74-033, July 1974.

U.S. Environmental Protection Agency, Nonpoint Source Control Guidance Hydrologic Modification, February 1977.

U.S. Environmental Protection Agency, Preliminary Results of the Nationwide Urban Runoff Program, Water Planning Division, January 1982.

U.S. Environmental Protection Agency, Preventive Approaches to Stormwater Management, EPA-440/9-77-001, January 1977.

U.S. Environmental Protection Agency, Proceedings National Conference on Urban Erosion and Sediment Control: Institutions and Technology, Great Lakes National Program Office, October 1980.

U.S. Environmental Protection Agency, Proceedings Urban Stormwater Management Seminars, Water Planning Division, Office of Water and Hazardous Materials, January 1976.

U.S. Environmental Protection Agency, Processes, Procedures and Methods to Control Pollution Resulting from All Construction Activity, EPA-430/9-73-007, October 1973.

U.S. Environmental Protection Agency, Restoration of Lakes and Inland Waters, Office of Water Regulations and Standards, December 1980.

U.S. Environmental Protection Agency, Urban Stormwater Management and Technology: An Assessment, National Environmental Research Center, Office of Research and Development, May 1974.

U.S. Environmental Protection Agency, Water Quality Management Planning For Urban Runoff, EPA-440/9-75-004, December 1974.

U.S. Environmental Protection Agency, Water-Related Environmental Fate of 129 Priority Pollutants, EPA-440/4-79-029A.

Urban Land Institute, American Society of Civil Engineers, National Association of Home Builders, Residential Storm Water Management Objectives, Principles and Design Considerations, 1975.

Uttormark, Paul D., Chapin, John D., Green, Kenneth M., Estimating Nutrient Loadings of Lakes From Non-Point Sources, Office of Research and Monitoring, U.S. Environmental Protection Agency, August 1974.

Veroni, Vito A., Sedimentation Engineering, ASCE (1974).

Viessman, Jr., Warren, Keating, Walter R., Srtnivasa, Kalkunte N., Urban Storm Runoff Relations, Water Resources Research, Vol. 6 No. 1, February 1970.

Walker, Rodger, Water Supply, Treatment and Distribution, Prentice-Hall, Inc., 1978.

Walker, William W., Water Quality Data Analysis, Model Development, and Model Applications for Lake Quinsigamond, META Systems, Inc., and Environmental Design and Planning, Inc. for Massachusetts Department of Environmental Quality Engineering, May 1981.

Wanielista, Martin P., Yousef, Yousef A, Golding, Bernard L., and Cassagnol, Claude, Stormwater Management Manual, University of Central Florida, Department of Civil Engineering and Environmental Sciences, October, 1981.

Water Pollution Control Federation, Design of Wastewater and Stormwater Pumping Stations, Manual of Practice No. FD-4, prepared by Task Force on Pumping Stations, 1980.

Water Pollution Control Federation, Operation and Maintenance of Wastewater Collection Systems, Manual of Practice No. 7, prepared by Task Force on Sanitary Sewer Maintenance, 1980.

Wechsler, B.A. and Cogley, D.R., A Laboratory Study of the Turbidity Generation Potential of Sediments to be Dredged, Tech. Rep. D-77-14,November 1977.

White, Charles A. and Franks, Alvin L., Demonstration of Erosion and Sediment Control Technology Lake Tahoe Region of California, Municipal Environmental Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, December 1978.

White, George Clifford, Disinfection of Wastewater and Water for Reuse, Van Nostrand Reinhold Company, 1978.

Whitman and Howard,Inc., A Study of Waste Septic Tank Sludge Disposal in Massachusetts, prepared for Massachusetts Division of Water Pollution Control, December 1976.

Worcester Planning Board and Worcester Planning Department, Subdivision Regulations of the City of Worcester, Massachusetts, September 1973.

Wullschleger, Richard E., Zanoni, Alphonse E., Hanson, Charles A., Methodology for the Study of Urban Generated Pollution and Control, EPA-600/2-77-145, August 1976.

Yu, KY., Chen, K.Y., Morrison, R.D., Physical and Chemical Characterization of Dredged Material Sediments and Leachates in Confined Land Disposal Areas , Tech. Rep. D-78-43, August 1978.

Benjes, Jr., Henry H., Cost Estimating Manual - Combined Sewer Overflow Storage and Treatment, EPA-600/2-76-286, December 1976.

Central Massachusetts Regional Planning Commission, Benthic Analysis Assabet River, Blackstone River, French River, Mill River, Mumford River, Quinebaug River, West River, February 1978.

Central Massachusetts Regional Planning Commission, Draft Environmental Impact Statement and Proposed 208 Water Quality Management Plan, December 1977.

Chow, Vente; Yen, Ben Chie, Urban Stormwater Runoff: Determination of Volumes and Flowrates, EPA-600/2-76-166, May 1976.

City of Worcester City Council, Zoning Ordinance of the City of Worcester, April 1980.

Conservation Law Foundation of New England, Inc., Environmental Bylaws.

Conservation Law Foundation of New England, Inc., Subdivision Control in Massachusetts, March 1976.

Cooke, Dennis G., Covering Bottom Sediments as a Lake Restoration Technique, Paper #80060, Vol. 16, No. 5, Bull., Water Resource, October 1980.

Cranker, Nancy A., Metal Toxicity in Aquatic Systems, Massachusetts Department of Environmental Quality Engineering, November 1980.

C.E. Maguire, Inc., Bottom Deposit Removal and/or Control Alternatives for the Blackstone River, Department of Environmental Quality Engineering, March 1981.

Vitale, Anne M., Sprey, Pierre M., Total Urban Water Pollution Loads: The Impact of Stormwater, Council on Environmental Quality, 1974.

Data Appendices

prepared for

Meta Systems, Inc.
Environmental Design and Planning, Inc.
Massachusetts Division of Water Pollution Control
U.S. Environmental Protection Agency

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Water Quality Stations - 1980

CODE	DEPTH (FT)	LOCATION
		FLINT POND
F01	15	POND, 800′ SO. INLET
F02	5	POND, 1500′ NO. RT.20
F03	15	POND, 2000′ SO. RT.20
F04	5	POND, 1500′ WEST IRISH DAM
F05	5	POND, @ RT.20 BRIDGE
F06		SOUTH MEADOW BROOK
F07		INLET FROM LK. QUINS.
F08	5	IRISH DAM OUTLET
F09		BONNIE BROOK
		LAKE QUINSIGAMOND
Q01	90	LAKE, 600′ SO. I-290
Q02	60	LAKE, 300′ NO. RT.9
Q03	80	LAKE, 300′ SO. RT.9
Q04	50	LAKE, 1000′ NO.BRIDLE PATH STM.DR.
Q05	40	LAKE @ I-290 BRIDGE
Q06	10	LAKE @ RT.9 BRIDGE
Q08		FITZGERALD BROOK
Q09		COALMINE BROOK
Q10		POOR FARM BROOK
Q11		NEWTON POND OUTLET
Q12	10	LAKE @ LINCOLN ST.
Q13		BILLINGS BROOK
Q15		O′HARA BROOK
Q16		MEDICAL SCHOOL DRAIN
Q17		TILLY BROOK
Q18		JORDAN POND OUTLET
Q19		BELMONT STREET DRAIN
Q20		CHANNEL BLW. BELMONT ST. DRAIN

Water Quality Variable Codes - 1980

No.	Code	Variable	Units
01	DOX	DISSOLVED OXYGEN	MG/L
02	TMP	TEMPERATURE	DEG. C
04	CHL	CHLOROPHYLL-A	MG/M3
05	TLA	TOTAL ALGAE	CELLS/ML
07	BGA	BLUE GREEN ALGAE	CELLS/ML
08	DIA	DIATOMS	CELLS/ML
09	FLA	FLAGELLATES	CELLS/ML
10	GRA	GREEN ALGAE	CELLS/ML
13	CND	CONDUCTIVITY	UHOS/CM
14	ALK	ALKALINITY	MG/L
15	HDN	HARDNESS	MG/L
16	PHU	PH	STD. UNITS
17	CLD	CHLORIDE	MG/L
18	SO4	SULFATE	MG/L
26	IRN	IRON	MG/L
27	MNG	MANGANESE	MG/L
28	TLN	TOTAL NITROGEN	MG/L
29	TKN	TOTAL KJELDAHL N	MG/L
30	ORN	ORGANIC N	MG/L
31	NH3	AMMONIA-N	MG/L
32	NO3	NITRATE-N	MG/L
33	INN	INORGANIC N	MG/L
34	TLP	TOTAL P	MG/L
35	TDP	TOTAL DISSOLVED P	MG/L
36	OTP	ORTHO P	MG/L
37	SIL	SILICA	MG/L
38	CLR	APPARENT COLOR	PT-CO UNITS
39	SEC	SECCHI DEPTH	FT
41	TSL	TOTAL SOLIDS	MG/L
42	SSL	SUSPENDED SOLIDS	MG/L
44	TCF	TOTAL COLIFORMS	COUNTS/100 ML
45	FCF	FECAL COLIFORMS	COUNTS/100 ML
46	FST	FECAL STREP	COUNTS/100 ML

Appendix A

1980 Data Listings

A-1 Temperature and Oxygen
A-2 Algae and Transparency
A-3 Bacteria and Solids
A-4 Other Chemical Data

```
STATION=F01 POND, 800 FT SO. INLET

YEAR MONTH DAY DEPTH  TMP DOX

 80     4     8  1.64  7.2 11.9
 80     4     8  2.00  7.2 11.9
 80     4     8  4.92  6.6 12.1
 80     4     8  9.84  6.1 12.1
 80     4     8 10.00  6.1 12.1
 80     4    24  0.00 10.0 11.6
 80     4    24  4.92 10.0 12.0
 80     4    24  9.84 10.0 11.8
 80     4    24 10.00  1.0 11.8
 80     5     6  0.00 13.8 10.7
 80     5     6  4.92 13.8 11.3
 80     5     6  9.84 13.8 10.8
 80     5     6 10.00 13.8 10.8
 80     5    21  0.00 17.0 10.4
 80     5    21  1.64 17.0   .
 80     5    21  3.28 17.0 10.4
 80     5    21  6.56 16.5   .
 80     5    21  9.84 16.5  9.8
 80     5    21 10.00 16.5  9.8
 80     6     2  0.00 20.5  8.0
 80     6     2  4.92 19.4  8.9
 80     6     2  9.84 19.4  8.8
 80     6     2 10.00 19.4  8.8
 80     6    19  0.00 22.0  9.4
 80     6    19  1.64 22.0  9.4
 80     6    19  4.92 22.0  9.0
 80     6    19  5.00 22.0  9.0
 80     6    19  6.56 22.0  9.6
 80     6    19  8.00 22.0  9.6
 80     7     2  0.00 20.6  8.5
 80     7     2  1.64 20.6  8.5
 80     7     2  4.92 20.0  8.4
 80     7     2  5.00 20.0  8.4
 80     7     2  8.00 19.5  6.6
 80     7     2  9.84 19.5  6.6
 80     7    17  0.00 27.8  9.3
 80     7    17  4.92 27.8  9.1
 80     7    17  5.00 27.8  9.1
 80     7    17  8.00 26.7  5.5
 80     7    17  9.84 26.7  5.5
 80     7    31  0.00 28.5  8.2
 80     7    31  4.92 26.5  7.2
 80     7    31  9.84 26.0  6.8
 80     7    31 10.00 26.4  6.8
 80     8    18  0.00 24.0  7.6
 80     8    18  4.92 23.5  6.6
 80     8    18  5.00 23.5  6.6
 80     8    18  9.84 23.0  6.1
 80     8    18 10.00 23.0  6.1
 80     8    26  0.00 24.5  8.6
 80     8    26  4.92 24.0  9.1
 80     8    26  5.00 24.0  9.1
 80     8    26  9.84 24.0  9.2
 80     8    26 10.00 24.0  9.2
```

```
STATION=F01 POND, 800 FT SO. INLET

YEAR MONTH DAY DEPTH TMP  DOX

 80     9   16   0.00 16.0 6.7
 80     9   16   4.92 16.0 8.0
 80     9   16   5.00 16.0 8.0
 80     9   16   6.56 16.0 7.7
 80     9   16   7.00 16.0 7.7
 80     9   30   0.00 16.0 7.9
 80     9   30   4.92 16.5 6.9
 80     9   30   5.00 16.5 6.9
 80     9   30   9.84 16.5 6.9
 80     9   30  10.00 16.5 6.9
 80    10   30   0.00  9.0 8.8
 80    10   30   4.92  7.5 9.0
 80    10   30   5.00  7.5 9.0
 80    10   30   9.84  7.5 8.7
 80    10   30  10.00  7.5 7.7
```

```
STATION=F02 POND, 1500 FT NO. RT.20

YEAR MONTH DAY DEPTH  TMP DOX

 80     4     8    0     7.7 11.7
 80     4    24    0     8.8 11.8
 80     5     6    0    15.5 10.2
 80     5    21    0    15.5  9.6
 80     6     2    0    20.0  8.7
 80     6    19    0    22.0  9.4
 80     7     2    0    20.0  8.0
 80     7    17    0    27.8  8.1
 80     7    31    0    29.0 10.0
 80     8    18    0    23.5  8.2
 80     8    26    0    24.5  8.5
 80     9    16    0    15.0  8.0
 80     9    30    0    14.5  7.5
 80    10    30    0     7.5  8.7
```

```
STATION=F03 POND, 2000 FT SO. RT.20

YEAR MONTH DAY DEPTH  TMP DOX

 80     4     8  1.64  7.7 11.5
 80     4     8  2.00  7.7 11.5
 80     4     8  6.56  7.7 10.8
 80     4     8 13.00  7.2 11.6
 80     4     8 13.12  7.2 11.6
 80     4    24  0.00 11.1 10.4
 80     4    24  3.28 10.0 10.3
 80     4    24 13.00 10.0 10.3
 80     4    24 13.12 10.0 10.3
 80     5     6  0.00 13.8 10.5
 80     5     6  6.56 13.8 10.3
 80     5     6 13.00 13.8  9.7
 80     5     6 13.12 13.8  9.7
```

```
STATION=F03 POND, 2000 FT SO. RT.2

YEAR MONTH DAY DEPTH TMP  DOX

 80     5   21   0.00 18.0 10.1
 80     5   21   4.92 18.0  9.5
 80     5   21  13.00 14.5  6.4
 80     5   21  13.12 14.5  6.4
 80     6    2   0.00 18.8  8.4
 80     6    2   4.92 14.4  8.5
 80     6   19   0.00 23.0  9.3
 80     6   19   1.64 23.0  9.3
 80     6   19   4.92 23.0  8.6
 80     6   19   7.00 23.0  8.6
 80     6   19  13.00 20.0  9.1
 80     6   19  13.12 20.0  9.1
 80     7    2   0.00 20.0  8.5
 80     7    2   4.92 20.0  8.3
 80     7    2   7.00 20.0  8.3
 80     7    2  13.00 20.0  5.9
 80     7    2  13.12 20.0  5.9
 80     7   17   0.00 27.8  9.0
 80     7   17   4.92 27.8  8.5
 80     7   17   7.00 27.8  8.5
 80     7   17   8.00 25.6  4.8
 80     7   17  13.12 25.6  4.8
 80     7   31   0.00 28.5  8.4
 80     7   31   4.92 28.0  8.6
 80     7   31  13.00 26.5  7.9
 80     7   31  13.12 26.5  7.9
 80     8   18   0.00 24.5  7.2
 80     8   18   4.92 24.5  7.0
 80     8   18   7.00 24.5  7.0
 80     8   18  13.00 24.5  6.2
 80     8   18  13.12 24.5  6.2
 80     8   26   0.00 24.0  9.6
 80     8   26   4.92 22.0 10.0
 80     8   26   7.00 22.0 10.0
 80     8   26  13.00 22.0  8.9
 80     8   26  13.12 22.0  8.9
 80     9   16   0.00 15.5  7.9
 80     9   16   4.92 16.5  7.8
 80     9   16   7.00 16.5  7.8
 80     9   16  13.00 16.5  6.8
 80     9   16  13.12 16.5  6.8
 80     9   30   0.00 16.5  8.2
 80     9   30   4.92 16.5  8.3
 80     9   30   7.00 16.5  8.3
 80     9   30  13.00 16.0  7.2
 80     9   30  13.12 16.0  7.0
 80    10   30   0.00  7.5  9.6
 80    10   30   4.92  6.5  9.8
 80    10   30   7.00  6.5  9.8
 80    10   30  13.00  6.5  9.4
 80    10   30  13.12  6.5  9.4
```

STATION=Q01 LAKE, 600 FT SO. I-290

YEAR	MONTH	DAY	DEPTH	TMP	DOX
80	5	6	25	9.5	.
80	5	6	30	9.0	10.7
80	5	6	35	8.5	.
80	5	6	40	8.0	9.8
80	5	6	45	7.5	.
80	5	6	50	7.0	9.3
80	5	6	55	7.0	.
80	5	6	60	7.0	9.3
80	5	6	65	7.0	.
80	5	6	70	6.5	8.8
80	5	6	75	6.5	.
80	5	6	80	6.5	7.4
80	5	6	85	6.5	.
80	5	6	90	6.5	7.0
80	5	21	0	17.0	11.1
80	5	21	5	16.0	.
80	5	21	10	16.0	10.4
80	5	21	15	14.0	.
80	5	21	20	12.5	11.9
80	5	21	25	11.0	.
80	5	21	30	9.5	9.8
80	5	21	35	9.0	.
80	5	21	40	8.5	8.6
80	5	21	45	8.0	.
80	5	21	50	7.5	7.6
80	5	21	55	7.0	.
80	5	21	60	7.0	7.5
80	5	21	65	7.0	.
80	5	21	70	7.0	6.8
80	5	21	75	7.0	.
80	5	21	80	7.0	6.1
80	5	21	85	7.0	.
80	5	21	90	7.0	4.4
80	6	2	0	20.0	9.6
80	6	2	5	19.5	.
80	6	2	10	19.0	8.6
80	6	2	15	18.0	.
80	6	2	20	13.5	9.4
80	6	2	25	11.0	.
80	6	2	30	9.5	7.9
80	6	2	35	8.5	.
80	6	2	40	7.5	6.2
80	6	2	45	7.5	.
80	6	2	50	7.0	.
80	6	2	55	7.0	.
80	6	2	60	7.0	6.6
80	6	2	70	7.0	5.7
80	6	2	80	7.0	.
80	6	2	85	6.5	2.7
80	6	19	0	22.0	10.2
80	6	19	5	21.0	.
80	6	19	10	20.0	8.3
80	6	19	15	19.0	.
80	6	19	20	15.0	10.1

STATION=Q01 LAKE, 600 FT SO. I-290

YEAR	MONTH	DAY	DEPTH	TMP	DOX
80	6	19	25	11.5	.
80	6	19	30	9.0	10.4
80	6	19	35	8.0	.
80	6	19	40	8.0	6.5
80	6	19	45	7.5	.
80	6	19	50	7.5	5.1
80	6	19	55	7.0	.
80	6	19	60	7.0	5.2
80	6	19	65	7.0	.
80	6	19	70	7.0	4.2
80	6	19	75	7.0	.
80	6	19	80	7.0	4.1
80	6	19	85	7.0	4.1
80	6	19	90	7.0	.
80	7	2	0	22.0	7.6
80	7	2	5	22.0	.
80	7	2	10	22.0	8.5
80	7	2	15	22.0	.
80	7	2	20	17.0	8.9
80	7	2	25	12.5	.
80	7	2	30	10.0	9.5
80	7	2	35	8.5	.
80	7	2	40	8.0	6.4
80	7	2	45	8.0	.
80	7	2	50	7.5	3.3
80	7	2	55	7.5	.
80	7	2	60	7.5	3.1
80	7	2	65	7.5	.
80	7	2	70	7.0	2.8
80	7	2	75	7.0	.
80	7	2	80	7.0	4.0
80	7	2	85	7.0	.
80	7	2	90	7.0	.
80	7	17	0	25.0	8.6
80	7	17	5	25.0	.
80	7	17	10	24.5	8.7
80	7	17	15	23.5	.
80	7	17	20	18.0	9.1
80	7	17	25	17.5	.
80	7	17	30	9.5	9.4
80	7	17	35	8.0	.
80	7	17	40	7.5	7.1
80	7	17	45	7.5	.
80	7	17	50	7.5	2.7
80	7	17	55	7.5	.
80	7	17	60	7.0	1.5
80	7	17	65	7.0	.
80	7	17	70	7.0	1.3
80	7	17	75	7.0	.
80	7	17	80	7.0	0.7
80	7	17	85	7.0	1.3
80	7	17	90	7.0	1.3
80	7	31	0	26.5	8.4
80	7	31	10	27.0	8.3

STATION=Q01 LAKE, 600 FT SO. I-290

YEAR	MONTH	DAY	DEPTH	TMP	DOX
80	7	31	20	23.5	9.3
80	7	31	25	15.0	10.2
80	7	31	30	12.0	7.7
80	7	31	40	10.0	1.5
80	7	31	50	9.0	0.7
80	7	31	60	9.0	0.3
80	7	31	70	8.5	0.2
80	7	31	80	8.5	0.0
80	7	31	90	8.0	0.0
80	8	18	0	24.0	8.9
80	8	18	5	23.5	.
80	8	18	10	23.0	7.1
80	8	18	15	23.0	.
80	8	18	20	20.0	8.6
80	8	18	25	13.0	.
80	8	18	30	10.0	6.6
80	8	18	35	9.0	.
80	8	18	40	8.0	2.9
80	8	18	45	8.0	.
80	8	18	50	7.5	0.6
80	8	18	55	7.5	.
80	8	18	60	7.5	0.7
80	8	18	65	7.5	.
80	8	18	70	7.0	0.2
80	8	18	75	7.0	.
80	8	18	80	7.0	0.0
80	8	18	85	7.0	0.0
80	8	18	90	7.0	.
80	8	26	0	24.0	9.1
80	8	26	5	23.0	.
80	8	26	10	22.0	9.2
80	8	26	15	21.5	.
80	8	26	20	20.0	9.4
80	8	26	25	13.0	.
80	8	26	30	10.0	7.2
80	8	26	35	8.5	.
80	8	26	40	8.0	3.1
80	8	26	45	7.5	.
80	8	26	50	7.5	1.9
80	8	26	55	7.5	.
80	8	26	60	7.5	2.4
80	8	26	65	7.0	.
80	8	26	70	7.0	2.3
80	8	26	75	7.0	.
80	8	26	80	7.0	1.5
80	8	26	85	7.0	.
80	8	26	90	7.0	.
80	9	16	0	20.5	9.3
80	9	16	5	20.5	.
80	9	16	10	20.8	9.7
80	9	16	15	20.0	.
80	9	16	20	20.0	9.2
80	9	16	25	14.0	.
80	9	16	30	10.0	2.7

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STATION=F04 POND, 1500 FT WEST IRISH DAM

YEAR	MONTH	DAY	DEPTH	TMP	DOX
80	4	8	0	8.8	11.1
80	4	24	0	9.4	10.6
80	5	8	0	15.0	8.5
80	5	21	0	15.5	8.5
80	6	2	0	20.0	8.1
80	6	19	0	22.0	7.9
80	7	2	0	20.0	8.4
80	7	17	0	27.8	8.1
80	7	31	0	29.0	9.2
80	8	18	0	23.0	8.3
80	8	26	0	24.0	8.5
80	9	16	0	14.5	7.3
80	9	30	0	14.5	9.6
80	10	30	0	5.5	9.7

STATION=F05 POND, @ RT.20 BRIDGE

YEAR	MONTH	DAY	DEPTH	TMP	DOX
80	4	8	0	8.3	11.3
80	4	24	0	8.8	11.0
80	5	6	0	15.0	10.0
80	5	21	0	15.5	8.5
80	6	2	0	20.0	8.7
80	6	19	0	22.0	7.9
80	7	2	0	20.6	8.3
80	7	17	0	27.8	5.8
80	7	31	0	29.0	9.2
80	8	18	0	23.0	7.3
80	8	26	0	24.0	8.5
80	9	16	0	14.5	7.4
80	9	30	0	14.5	8.8
80	10	30	0	5.5	8.9

STATION=F06 SOUTH MEADOW BROOK

YEAR	MONTH	DAY	DEPTH	TMP	DOX
80	3	3	0	1.1	9.6
80	4	8	0	7.7	5.5
80	4	24	0	7.7	9.6
80	5	6	0	13.0	6.3
80	5	21	0	13.0	6.2
80	6	2	0	17.0	8.0
80	6	19	0	20.0	9.2
80	7	2	0	18.0	4.0
80	7	17	0	23.0	7.2
80	7	31	0	21.0	2.6
80	8	18	0	19.0	7.2
80	8	26	0	19.0	4.9
80	9	16	0	14.0	5.1
80	9	30	0	10.0	7.4

STATION=F06 SOUTH MEADOW BROOK

YEAR	MONTH	DAY	DEPTH	TMP	DOX
80	10	30	0	3.0	7.4
80	11	13	0	1.0	10.1

STATION=F07 INLET FROM LK. QUINS.

YEAR	MONTH	DAY	DEPTH	TMP	DOX
80	3	3	0	1.1	14.4
80	4	8	0	6.6	12.0
80	4	24	0	10.0	12.4
80	5	6	0	15.0	11.2
80	5	21	0	17.0	11.7
80	6	2	0	21.0	10.0
80	6	19	0	23.0	10.5
80	7	2	0	17.5	8.6
80	7	17	0	27.0	9.0
80	7	31	0	26.0	8.0
80	8	18	0	25.0	8.7
80	8	26	0	24.0	8.7
80	9	16	0	16.0	7.0
80	9	30	0	20.0	7.4
80	10	30	0	8.0	8.6
80	11	13	0	4.0	10.6

STATION=F08 IRISH DAM OUTLET

YEAR	MONTH	DAY	DEPTH	TMP	DOX
80	3	3	0	2.2	8.6
80	4	8	0	8.3	11.2
80	4	24	0	9.4	10.6
80	5	6	0	17.0	8.8
80	5	21	0	19.0	8.3
80	6	2	0	22.0	7.7
80	6	19	0	25.0	7.5
80	7	2	0	22.0	8.6
80	7	17	0	27.0	7.8
80	7	31	0	26.0	7.7
80	8	18	0	23.0	6.0
80	8	26	0	24.0	7.2
80	9	16	0	16.0	3.7
80	9	30	0	16.0	6.8
80	10	30	0	5.0	10.7
80	11	13	0	0.0	12.6

STATION=F09 BONNIE BROOK

YEAR	MONTH	DAY	DEPTH	TMP	DOX
80	4	24	0	10.0	11.0
80	5	6	0	14.0	9.3
80	5	21	0	14.0	7.7
80	6	2	0	21.0	6.9
80	6	19	0	25.0	7.7
80	7	2	0	21.5	7.8
80	7	17	0	27.0	6.3
80	7	31	0	23.0	6.5
80	8	18	0	23.0	7.8
80	8	26	0	23.0	8.0
80	9	16	0	21.0	8.1
80	9	30	0	16.0	8.6
80	10	30	0	10.0	9.1
80	11	13	0	11.0	9.4

STATION=Q01 LAKE, 600 FT SO. I-290

YEAR	MONTH	DAY	DEPTH	TMP	DOX
80	4	8	0	6.5	-
80	4	8	5	6.5	.
80	4	8	10	6.5	14.3
80	4	8	15	6.0	.
80	4	8	20	6.0	11.7
80	4	8	25	6.0	.
80	4	8	30	6.0	10.6
80	4	8	35	6.0	.
80	4	8	40	5.5	11.6
80	4	8	45	5.5	.
80	4	8	50	5.5	11.8
80	4	8	55	5.5	.
80	4	8	60	5.5	11.1
80	4	8	65	5.0	.
80	4	8	70	5.0	11.1
80	4	8	75	5.0	.
80	4	8	80	5.0	11.3
80	4	8	85	5.0	.
80	4	8	90	5.0	11.0
80	4	24	0	10.0	11.9
80	4	24	10	9.5	12.7
80	4	24	20	9.0	11.9
80	4	24	30	8.5	11.8
80	4	24	40	7.5	10.5
80	4	24	50	6.5	10.3
80	4	24	60	6.5	10.0
80	4	24	70	6.5	10.7
80	4	24	80	6.0	10.2
80	4	24	85	6.0	9.3
80	5	6	0	15.0	11.2
80	5	6	5	13.5	.
80	5	6	10	12.0	11.7
80	5	6	15	11.0	.
80	5	6	20	10.0	11.5

STATION=Q01 LAKE, 600 FT SO. I-290

YEAR	MONTH	DAY	DEPTH	TMP	DOX
80	9	16	35	8.5	.
80	9	16	40	8.0	0.6
80	9	16	45	7.5	.
80	9	16	50	7.0	0.7
80	9	16	55	7.0	.
80	9	16	60	7.0	0.5
80	9	16	65	7.0	.
80	9	16	70	7.0	0.0
80	9	16	75	6.5	.
80	9	16	80	6.5	0.0
80	9	30	0	17.0	8.0
80	9	30	5	16.5	.
80	9	30	10	16.5	8.4
80	9	30	15	16.5	.
80	9	30	20	16.5	8.5
80	9	30	25	16.0	.
80	9	30	30	9.0	6.8
80	9	30	35	7.5	.
80	9	30	40	6.0	0.5
80	9	30	45	5.5	.
80	9	30	50	5.5	0.3
80	9	30	55	5.0	.
80	9	30	60	5.0	0.4
80	9	30	65	5.0	.
80	9	30	70	5.0	0.4
80	9	30	75	5.0	.
80	9	30	80	5.0	0.0
80	9	30	85	5.0	0.0
80	9	30	90	5.0	.
80	10	30	0	11.0	7.9
80	10	30	10	10.5	7.9
80	10	30	20	10.5	7.9
80	10	30	30	10.5	7.9
80	10	30	35	10.0	.
80	10	30	40	8.0	7.0
80	10	30	45	7.5	.
80	10	30	50	7.5	1.3
80	10	30	60	7.5	1.4
80	10	30	70	7.5	0.0
80	10	30	80	7.0	0.0
80	10	30	90	6.5	0.0
80	11	13	0	7.5	5.9
80	11	13	5	7.5	.
80	11	13	10	7.5	6.3
80	11	13	15	7.5	.
80	11	13	20	7.5	.
80	11	13	25	7.5	.
80	11	13	30	7.5	6.3
80	11	13	35	7.5	.
80	11	13	40	7.5	6.2
80	11	13	45	7.5	.
80	11	13	50	7.5	6.3
80	11	13	55	7.5	.
80	11	13	60	7.5	6.1

STATION=Q01 LAKE, 600 FT SO. I-290

YEAR	MONTH	DAY	DEPTH	TMP	DOX
80	11	13	65	7.5	.
80	11	13	70	7.5	6.2
80	11	13	75	7.5	.
80	11	13	80	7.5	6.0

STATION=Q02 LAKE, 300 FT NO. RT.9

YEAR	MONTH	DAY	DEPTH	TMP	DOX
80	4	8	0	6.5	11.7
80	4	8	5	6.0	.
80	4	8	10	6.0	.
80	4	8	15	6.0	.
80	4	8	20	6.0	12.0
80	4	8	25	6.0	.
80	4	8	30	6.0	.
80	4	8	35	6.0	.
80	4	8	40	6.0	.
80	4	8	45	6.0	.
80	4	8	50	5.5	.
80	4	8	55	5.5	.
80	4	8	60	5.5	11.7
80	4	24	0	10.0	11.6
80	4	24	5	10.0	.
80	4	24	10	10.0	11.9
80	4	24	15	9.5	.
80	4	24	20	9.0	11.6
80	4	24	25	9.0	.
80	4	24	30	8.5	11.4
80	4	24	35	8.0	.
80	4	24	40	7.5	10.8
80	4	24	45	7.0	.
80	4	24	50	7.0	10.0
80	4	24	55	6.5	.
80	4	24	60	6.5	10.6
80	5	6	0	14.0	11.4
80	5	6	5	13.5	.
80	5	6	10	13.0	11.3
80	5	6	15	12.5	.
80	5	6	20	11.5	11.8
80	5	6	25	10.5	.
80	5	6	30	9.5	10.7
80	5	6	35	9.5	.
80	5	6	40	8.0	9.7
80	5	6	45	7.5	.
80	5	6	50	7.0	8.8
80	5	6	55	7.0	.
80	5	6	60	7.0	9.1
80	5	21	0	17.0	10.1
80	5	21	5	17.0	.
80	5	21	10	17.0	10.4
80	5	21	15	16.0	.
80	5	21	20	13.0	10.8

STATION=Q02 LAKE, 300 FT NO. RT.9

YEAR	MONTH	DAY	DEPTH	TMP	DOX
80	5	21	25	11.0	.
80	5	21	30	9.0	9.4
80	5	21	35	8.0	.
80	5	21	40	8.0	8.9
80	5	21	45	7.5	.
80	5	21	50	7.0	7.2
80	5	21	55	7.0	.
80	5	21	60	7.0	6.5
80	6	2	0	20.0	9.7
80	6	2	5	19.5	.
80	6	2	10	18.0	10.1
80	6	2	15	17.5	.
80	6	2	20	14.0	11.5
80	6	2	25	11.0	.
80	6	2	30	9.5	9.9
80	6	2	35	8.0	.
80	6	2	40	7.5	5.1
80	6	2	45	7.5	.
80	6	2	50	7.0	6.8
80	6	2	55	7.0	.
80	6	2	60	7.0	5.2
80	6	19	0	21.5	8.4
80	6	19	5	20.0	.
80	6	19	10	20.0	7.1
80	6	19	15	19.0	.
80	6	19	20	15.0	9.3
80	6	19	25	11.0	.
80	6	19	30	9.0	9.9
80	6	19	35	8.5	.
80	6	19	40	8.0	6.4
80	6	19	45	7.5	.
80	6	19	50	7.5	7.3
80	6	19	55	7.0	4.5
80	6	19	60	7.0	.
80	7	2	0	22.5	8.6
80	7	2	5	22.0	.
80	7	2	10	21.0	8.5
80	7	2	15	20.0	.
80	7	2	20	17.0	10.4
80	7	2	25	13.0	.
80	7	2	30	10.0	9.2
80	7	2	35	9.0	.
80	7	2	40	8.0	7.2
80	7	2	45	8.0	.
80	7	2	50	7.5	4.9
80	7	2	55	7.5	2.2
80	7	2	60	7.0	.
80	7	17	0	25.0	8.8
80	7	17	5	24.5	.
80	7	17	10	24.0	9.1
80	7	17	15	22.5	.
80	7	17	20	15.0	9.5
80	7	17	25	12.0	.
80	7	17	30	9.5	11.2

```
STATION=Q02 LAKE, 300 FT NO. RT.9

YEAR MONTH DAY DEPTH  TMP DOX

 80     7   17    35    8.0   .
 80     7   17    40    7.5  8.7
 80     7   17    45    7.5   .
 80     7   17    50    7.5  2.5
 80     7   17    55    7.0   .
 80     7   17    60    7.0  1.8
 80     7   31     0   26.5  8.5
 80     7   31    10   26.0  8.8
 80     7   31    20   23.5  9.6
 80     7   31    25   18.0 11.9
 80     7   31    30   13.0 10.1
 80     7   31    40    9.5  2.8
 80     7   31    50    8.5  1.1
 80     7   31    60    9.0  0.1
 80     8   18     0   24.0  8.5
 80     8   18     5   23.5   .
 80     8   18    10   23.5  8.9
 80     8   18    15   23.0   .
 80     8   18    20   19.5  9.6
 80     8   18    25   13.0   .
 80     8   18    30   10.0  9.3
 80     8   18    35    8.5   .
 80     8   18    40    8.0  3.2
 80     8   18    45    7.5   .
 80     8   18    50    7.5  1.2
 80     8   18    55    7.5   .
 80     8   18    60    7.0  0.8
 80     8   26     0   24.5  9.4
 80     8   26     5   23.0   .
 80     8   26    10   22.0  9.4
 80     8   26    15   21.5   .
 80     8   26    20   20.5  9.0
 80     8   26    25   13.5  8.6
 80     8   26    30   10.5  6.1
 80     8   26    35    9.0   .
 80     8   26    40    8.0  1.9
 80     8   26    45    7.5   .
 80     8   26    50    7.5  1.9
 80     8   26    55    7.5  1.7
 80     8   26    60    7.0   .
 80     9   16     0   20.5  9.4
 80     9   16     5   20.5   .
 80     9   16    10   20.0  9.5
 80     9   16    15   20.0   .
 80     9   16    20   20.0  9.5
 80     9   16    25   15.0   .
 80     9   16    30   10.0  5.7
 80     9   16    35    8.5   .
 80     9   16    40    8.0  0.7
 80     9   16    45    8.0   .
 80     9   16    50    7.5  0.6
 80     9   16    55    7.5   .
 80     9   16    60    7.5  0.0
 80     9   30     0   17.0  8.2
```

```
STATION=Q02 LAKE, 300 FT NO. RT.9

YEAR MONTH DAY DEPTH TMP  DOX

 80     9   30     5   16.5  .
 80     9   30    10   16.5 8.4
 80     9   30    15   16.5  .
 80     9   30    20   16.5 8.3
 80     9   30    25   16.5  .
 80     9   30    30    9.5 7.8
 80     9   30    35    7.0  .
 80     9   30    40    6.5 0.5
 80     9   30    45    6.0  .
 80     9   30    50    6.0 0.4
 80     9   30    55    6.0  .
 80     9   30    60    5.5 0.5
 80    10   30     0   11.0 8.3
 80    10   30    10   10.5 8.5
 80    10   30    20   10.5 8.3
 80    10   30    25   10.5  .
 80    10   30    30   10.5 8.1
 80    10   30    35   10.0  .
 80    10   30    40    8.0 8.4
 80    10   30    45    7.5  .
 80    10   30    50    7.5 1.3
 80    10   30    60    7.0 0.5
 80    11   13     0    7.5 8.3
 80    11   13     5    7.5  .
 80    11   13    10    7.5 8.2
 80    11   13    15    7.5  .
 80    11   13    20    7.5 8.4
 80    11   13    25    7.5  .
 80    11   13    30    7.5 8.3
 80    11   13    35    7.5  .
 80    11   13    40    7.5 8.3
 80    11   13    45    7.5  .
 80    11   13    50    7.5 8.1
 80    11   13    55    7.5  .
 80    11   13    60    7.5 8.1
 80    11   13    65    7.5 8.1
```

```
STATION=Q03 LAKE, 300 FT SO. RT.9

YEAR MONTH DAY DEPTH  TMP DOX

 80     4     8    0    7.0 11.5
 80     4     8    5    6.5   .
 80     4     8   10    6.5   .
 80     4     8   15    6.5   .
 80     4     8   20    6.0 11.1
 80     4     8   25    6.0   .
 80     4     8   30    6.0   .
 80     4     8   35    6.0   .
 80     4     8   40    6.0   .
 80     4     8   45    5.5   .
 80     4     8   50    5.5   .
 80     4     8   55    5.5   .
```

```
STATION=Q03 LAKE, 300 FT SO. RT.9

YEAR MONTH DAY DEPTH  TMP DOX

 80     4     8   60   5.5    .
 80     4     8   65   5.5    .
 80     4     8   70   5.5    .
 80     4     8   75   5.5    .
 80     4     8   80   5.5 10.5
 80     4    24    0   9.5 11.8
 80     4    24    5   9.5    .
 80     4    24   10   9.0 11.8
 80     4    24   15   9.0    .
 80     4    24   20   9.0 11.8
 80     4    24   25   9.0    .
 80     4    24   30   8.5 11.4
 80     4    24   35   8.0    .
 80     4    24   40   8.0 10.9
 80     4    24   45   7.0    .
 80     4    24   50   6.5  9.8
 80     4    24   55   6.5    .
 80     4    24   60   6.5  9.3
 80     4    24   65   6.0    .
 80     4    24   70   6.0  9.9
 80     4    24   75   6.0  9.8
 80     4    24   80   6.0    .
 80     5     6    0  14.0 11.3
 80     5     6    5  13.5    .
 80     5     6   10  13.0 11.4
 80     5     6   15  11.5    .
 80     5     6   20  11.0 11.6
 80     5     6   25  10.5    .
 80     5     6   30   9.5 10.3
 80     5     6   35   9.0    .
 80     5     6   40   8.5  9.4
 80     5     6   45   7.5    .
 80     5     6   50   7.0 13.9
 80     5     6   55   6.5    .
 80     5     6   60   6.5  7.6
 80     5     6   65   6.5    .
 80     5     6   70   6.5  7.1
 80     5     6   75   6.5    .
 80     5     6   80   6.5  7.2
 80     5    21    0  16.5 10.7
 80     5    21    5  17.0    .
 80     5    21   10  16.0 10.6
 80     5    21   15  14.0    .
 80     5    21   20  13.0 11.1
 80     5    21   25  11.0    .
 80     5    21   30  10.0  8.4
 80     5    21   35   9.0    .
 80     5    21   40   8.0  7.4
 80     5    21   45   8.0    .
 80     5    21   50   7.5  7.5
 80     5    21   55   7.0    .
 80     5    21   60   7.0  5.4
 80     5    21   65   7.0    .
 80     5    21   70   7.0  3.6
```

```
STATION=Q03 LAKE, 300 FT SO. RT.9

YEAR MONTH DAY DEPTH  TMP DOX

 80    5   21   75    7.0  .
 80    5   21   80    7.0  1.1
 80    6    2    0   21.0  9.6
 80    6    2    5   20.0  .
 80    6    2   10   19.5  9.9
 80    6    2   15   17.0  .
 80    6    2   20   13.5 10.2
 80    6    2   25   11.0  .
 80    6    2   30   10.0  9.9
 80    6    2   35    9.5  .
 80    6    2   40    9.0  6.5
 80    6    2   45    8.0  .
 80    6    2   50    7.0  7.0
 80    6    2   55    7.0  .
 80    6    2   60    6.5  4.1
 80    6    2   65    6.0  .
 80    6    2   70    6.0  1.9
 80    6    2   80    6.0  2.3
 80    6   19    0   21.5  9.0
 80    6   19    5   20.5  .
 80    6   19   10   20.0  8.8
 80    6   19   15   18.5  .
 80    6   19   20   14.0  9.6
 80    6   19   25   11.5  .
 80    6   19   30   10.0  8.9
 80    6   19   35    9.0  .
 80    6   19   40    9.0  4.8
 80    6   19   45    8.0  .
 80    6   19   50    7.5  4.2
 80    6   19   55    7.0  .
 80    6   19   60    6.5  4.8
 80    6   19   65    6.5  .
 80    6   19   70    6.5  1.1
 80    6   19   75    6.0  .
 80    6   19   80    6.0  1.1
 80    7    2    0   22.5  8.8
 80    7    2    5   22.0  .
 80    7    2   10   22.0  8.8
 80    7    2   15   21.0  .
 80    7    2   20   16.5  8.7
 80    7    2   25   12.5  .
 80    7    2   30   10.5  7.9
 80    7    2   35    9.5  .
 80    7    2   40    9.0  5.5
 80    7    2   45    8.5  .
 80    7    2   50    8.0  4.8
 80    7    2   55    7.5  .
 80    7    2   60    7.0  3.6
 80    7    2   65    6.5  .
 80    7    2   70    6.5  0.1
 80    7    2   75    6.5  .
 80    7    2   80    6.5  .
 80    7   17    0   25.0  8.9
 80    7   17    5   25.0  .
```

```
STATION=Q03 LAKE, 300 FT SO. RT.9

YEAR MONTH DAY DEPTH TMP  DOX

 80    7   17   10   24.0  8.8
 80    7   17   15   22.0  .
 80    7   17   20   16.5 10.4
 80    7   17   25   12.0  .
 80    7   17   30   10.0 10.2
 80    7   17   35    9.5  .
 80    7   17   40    9.0  2.0
 80    7   17   45    8.0  .
 80    7   17   50    7.5  1.5
 80    7   17   55    7.0  .
 80    7   17   60    6.5  0.6
 80    7   17   65    6.5  .
 80    7   17   70    6.5  0.5
 80    7   17   75    6.0  .
 80    7   17   80    6.0  0.0
 80    7   31    0   27.5  9.0
 80    7   31   10   26.0  8.9
 80    7   31   20   23.0 12.2
 80    7   31   25   19.5 12.2
 80    7   31   30   14.5  7.3
 80    7   31   40   11.5  0.6
 80    7   31   50   11.0  0.2
 80    7   31   60    8.5  0.0
 80    7   31   70    8.0  0.0
 80    7   31   75    8.0  0.0
 80    7   31   80    8.0  0.0
 80    8   18    0   23.5  8.7
 80    8   18    5   23.0  .
 80    8   18   10   23.0  8.7
 80    8   18   15   23.0  .
 80    8   18   20   18.0  8.6
 80    8   18   25   13.5  .
 80    8   18   30   11.0  7.2
 80    8   18   35   10.0  .
 80    8   18   40    9.0  2.9
 80    8   18   45    8.5  .
 80    8   18   50    8.0  0.3
 80    8   18   55    7.0  .
 80    8   18   60    7.0  0.0
 80    8   18   65    7.0  .
 80    8   18   70    6.5  0.0
 80    8   18   75    6.5  .
 80    8   18   80    6.0  0.0
 80    8   26    0   24.0  8.8
 80    8   26    5   23.0  .
 80    8   26   10   22.5  8.9
 80    8   26   15   21.5  .
 80    8   26   20   19.0  8.5
 80    8   26   25   13.0  .
 80    8   26   30   10.5  4.5
 80    8   26   35   10.0  .
 80    8   26   40    9.0  1.8
 80    8   26   45    8.5  .
 80    8   26   50    8.0  0.3
```

```
STATION=Q03 LAKE, 300 FT SO. RT.9

YEAR MONTH DAY DEPTH  TMP DOX

 80    8   26   55    7.5 .
 80    8   26   60    7.0 0.0
 80    8   26   65    6.5 .
 80    8   26   70    6.5 0.0
 80    8   26   75    6.5 0.0
 80    8   26   80    6.5 .
 80    9   16    0   20.5 9.1
 80    9   16    5   20.5 .
 80    9   16   10   20.0 9.3
 80    9   16   15   20.0 .
 80    9   16   20   20.0 9.1
 80    9   16   25   14.0 .
 80    9   16   30   11.0 1.4
 80    9   16   35   10.0 .
 80    9   16   40    9.5 1.0
 80    9   16   45    9.0 .
 80    9   16   50    8.0 0.0
 80    9   16   55    7.5 .
 80    9   16   60    7.0 0.0
 80    9   16   65    7.0 .
 80    9   16   70    6.5 0.0
 80    9   16   75    6.5 0.0
 80    9   16   80    6.5 0.0
 80    9   30    0   17.0 7.9
 80    9   30    5   16.5 .
 80    9   30   10   16.5 7.9
 80    9   30   15   16.5 .
 80    9   30   20   16.5 7.8
 80    9   30   25   15.0 .
 80    9   30   30   10.0 4.4
 80    9   30   35    8.5 .
 80    9   30   40    8.0 0.4
 80    9   30   45    7.5 .
 80    9   30   50    6.5 0.5
 80    9   30   55    6.0 .
 80    9   30   60    5.5 0.5
 80    9   30   65    5.0 .
 80    9   30   70    5.0 0.0
 80    9   30   75    5.0 .
 80    9   30   80    5.0 0.0
 80   10   30    0   10.5 7.3
 80   10   30   10   10.5 8.1
 80   10   30   20   10.5 6.8
 80   10   30   25   10.5 .
 80   10   30   30   10.5 7.0
 80   10   30   35   10.5 .
 80   10   30   40   10.5 6.6
 80   10   30   45    8.5 .
 80   10   30   50    8.0 1.5
 80   10   30   60    7.5 0.2
 80   10   30   70    7.0 0.0
 80   10   30   80    7.0 0.0
 80   11   13    0    7.5 7.8
 80   11   13    5    7.5 .
```

STATION=Q03 LAKE, 300 FT SO. RT.9

YEAR	MONTH	DAY	DEPTH	TMP	DOX
80	11	13	10	7.5	7.6
80	11	13	15	7.5	.
80	11	13	20	7.5	7.3
80	11	13	25	7.5	.
80	11	13	30	7.5	7.3
80	11	13	35	7.5	.
80	11	13	40	7.5	7.1
80	11	13	45	7.5	.
80	11	13	50	7.5	7.7
80	11	13	55	7.5	.
80	11	13	60	7.5	7.3
80	11	13	65	7.5	.
80	11	13	70	7.5	7.3
80	11	13	75	7.5	.
80	11	13	80	7.5	7.4

STATION=Q04 LAKE, 1000 FT NO.BRIDLE

YEAR	MONTH	DAY	DEPTH	TMP	DOX
80	4	8	0	8.0	12.1
80	4	8	5	7.0	.
80	4	8	10	7.0	.
80	4	8	15	7.0	.
80	4	8	20	7.0	11.4
80	4	8	25	6.5	.
80	4	8	30	6.0	.
80	4	8	35	6.0	.
80	4	8	40	6.0	.
80	4	8	45	6.0	.
80	4	8	50	5.5	11.9
80	4	24	0	10.5	11.1
80	4	24	10	10.0	11.5
80	4	24	20	10.0	11.7
80	4	24	30	8.0	10.9
80	4	24	40	7.5	9.7
80	4	24	45	7.0	8.1
80	5	6	0	14.0	11.4
80	5	6	5	13.5	.
80	5	6	10	13.0	11.4
80	5	6	15	12.5	.
80	5	6	20	11.0	11.2
80	5	6	25	10.0	.
80	5	6	30	9.5	9.6
80	5	6	35	8.5	.
80	5	6	40	7.5	8.0
80	5	6	45	7.0	.
80	5	6	50	7.0	4.6
80	5	21	0	17.0	10.6
80	5	21	5	17.0	.
80	5	21	10	17.0	10.6
80	5	21	15	16.0	.
80	5	21	20	13.0	11.2

STATION=Q04 LAKE, 1000 FT NO.BRIDLE PATH

YEAR	MONTH	DAY	DEPTH	TMP	DOX
80	5	21	25	11.0	.
80	5	21	30	9.5	6.7
80	5	21	35	9.0	.
80	5	21	40	8.0	3.9
80	5	21	45	7.0	.
80	5	21	50	7.0	0.5
80	6	2	0	20.0	9.5
80	6	2	5	20.0	.
80	6	2	10	19.5	9.8
80	6	2	15	17.0	.
80	6	2	20	13.0	1.0
80	6	2	25	10.5	.
80	6	2	30	9.5	6.6
80	6	2	35	8.5	.
80	6	2	40	7.5	0.9
80	6	2	45	7.0	.
80	6	2	50	7.0	0.9
80	6	19	0	21.0	8.6
80	6	19	5	20.5	.
80	6	19	10	20.0	9.4
80	6	19	15	18.5	.
80	6	19	20	15.0	9.6
80	6	19	25	11.0	.
80	6	19	30	10.0	4.0
80	6	19	35	9.0	.
80	6	19	40	8.0	1.9
80	6	19	45	7.0	0.0
80	6	19	50	7.0	.
80	7	2	0	22.0	8.1
80	7	2	5	22.0	.
80	7	2	10	22.0	7.7
80	7	2	15	20.0	.
80	7	2	20	17.0	9.6
80	7	2	25	12.0	.
80	7	2	30	10.0	4.4
80	7	2	35	9.0	.
80	7	2	40	8.0	1.1
80	7	2	45	7.0	1.5
80	7	2	50	7.0	.
80	7	17	0	25.0	8.6
80	7	17	5	25.0	.
80	7	17	10	24.0	9.5
80	7	17	15	22.0	.
80	7	17	20	16.5	10.0
80	7	17	25	12.0	.
80	7	17	30	10.0	3.3
80	7	17	35	8.0	.
80	7	17	40	7.5	0.4
80	7	17	45	7.0	0.0
80	7	17	50	7.0	0.0
80	7	31	0	28.0	8.7
80	7	31	10	27.0	9.0
80	7	31	20	23.5	10.7
80	7	31	25	19.0	8.3

STATION=Q04 LAKE, 1000 FT NO.BRIDLE PATH STM.DR

YEAR	MONTH	DAY	DEPTH	TMP	DOX
80	7	31	30	15.5	6.0
80	7	31	40	11.0	0.0
80	7	31	45	10.0	0.0
80	7	31	50	10.0	0.0
80	8	18	0	24.0	8.5
80	8	18	5	24.0	.
80	8	18	10	23.5	8.5
80	8	18	15	23.5	.
80	8	18	20	17.0	6.9
80	8	18	25	12.5	.
80	8	18	30	10.5	0.7
80	8	18	35	9.0	.
80	8	18	40	6.0	0.1
80	8	18	45	7.0	0.0
80	8	18	50	7.0	0.0
80	8	26	0	24.0	8.9
80	8	26	5	23.0	.
80	8	26	10	22.0	9.0
80	8	26	15	21.0	.
80	8	26	20	19.0	8.2
80	8	26	25	13.6	.
80	8	26	30	10.5	1.3
80	8	26	35	9.0	.
80	8	26	40	8.0	0.0
80	8	26	45	7.0	0.0
80	8	26	50	7.0	.
80	9	16	0	20.5	9.0
80	9	16	5	20.5	.
80	9	16	10	20.5	9.0
80	9	16	15	20.0	.
80	9	16	20	20.0	9.0
80	9	16	25	14.0	.
80	9	16	30	11.0	2.3
80	9	16	35	9.0	.
80	9	16	40	8.0	0.0
80	9	16	45	7.5	0.0
80	9	16	50	7.0	0.0
80	9	30	0	17.0	7.5
80	9	30	5	16.5	.
80	9	30	10	16.5	7.8
80	9	30	15	16.5	.
80	9	30	20	16.5	7.6
80	9	30	25	14.0	.
80	9	30	30	10.0	0.5
80	9	30	35	7.5	.
80	9	30	40	6.5	0.0
80	9	30	45	6.0	.
80	9	30	50	5.5	0.0
80	10	30	0	10.5	7.8
80	10	30	5	10.5	.
80	10	30	10	10.5	7.2
80	10	30	15	10.5	.
80	10	30	20	10.5	7.4
80	10	30	25	10.5	.

```
STATION=Q04 LAKE, 1000 FT NO.BRIDLE PATH STM.DR

YEAR MONTH DAY DEPTH TMP  DOX

 80   10   30   30   10.5  7.7
 80   10   30   35   10.0   .
 80   10   30   40    7.5  7.4
 80   10   30   45    7.0  4.7
 80   10   30   50    7.0  0.0
 80   11   13    0    7.5 10.4
 80   11   13    5    7.5   .
 80   11   13   10    7.5 10.4
 80   11   13   15    7.5   .
 80   11   13   20    7.5 10.4
 80   11   13   25    7.5   .
 80   11   13   30    7.5 10.4
 80   11   13   35    7.5   .
 80   11   13   40    7.5 10.6
 80   11   13   45    7.5 10.5
 80   11   13   50    7.5 10.5
```

```
STATION=Q05 LAKE @ I-290 BRIDGE

YEAR MONTH DAY DEPTH  TMP DOX

 80    4     8    0    6.1 12.0
 80    4    24    0   10.0 12.0
 80    5     6    0   13.3 11.5
 80    5    21    0   17.0 10.6
 80    6     2    0   20.0  9.6
 80    6    19    0   19.0  8.1
 80    7     2    0   22.5  9.2
 80    7    17    0   25.5  8.7
 80    7    31    0   29.0  9.2
 80    8    18    0   24.5  8.8
 80    8    26    0   24.0  8.2
 80    9    16    0   20.5  8.3
 80    9    30    0   17.0  7.4
 80   10    30    0   10.5  8.1
 80   11    13    0    7.5  7.0
```

```
STATION=Q06 LAKE @ RT.9 BRIDGE

YEAR MONTH DAY DEPTH  TMP DOX

 80    4     8    0    5.5 12.2
 80    4    24    0   10.0 11.5
 80    5     6    0   13.5 11.3
 80    5    21    0   17.0 10.3
 80    6     2    0   20.0  9.9
 80    6    19    0   20.5  8.6
 80    7     2    0   22.5  9.0
 80    7    17    0   25.0  9.4
 80    8    18    0   24.5  8.7
 80    8    26    0   24.0  8.7
 80    9    16    0   20.5  9.4
```

```
STATION=Q06 LAKE @ RT.9 BRIDGE

YEAR MONTH DAY DEPTH TMP  DOX

 80    9    30    0   17.0 8.5
 80   10    30    0   10.5 8.2
 80   11    13    0    7.5 7.3
```

```
STATION=Q08 FITZGERALD BROOK

YEAR MONTH DAY DEPTH  TMP DOX

 80    3     3    0    0.0 14.0
 80    4     8    0    5.5 10.7
 80    4    24    0    8.8 12.4
 80    5     6    0   11.0 12.1
 80    5    21    0   12.0 11.0
 80    6     2    0   15.0  8.0
 80    6    19    0   14.0  8.8
 80    7     2    0   16.0  9.3
 80    7    17    0   18.0 10.2
 80    7    31    0   19.0  8.6
 80    8    18    0   17.0  7.5
 80    8    26    0   18.0  9.0
 80   10    30    0    7.0 11.1
 80   11    13    0    6.0 11.2
```

```
STATION=Q09 COALMINE BROOK

YEAR MONTH DAY DEPTH TMP  DOX

 80    3     3    0   -0.5 14.5
 80    4     8    0    5.5 11.9
 80    4    24    0   10.0 11.9
 80    5     6    0   13.0 11.8
 80    5    21    0   11.0 14.9
 80    6     2    0   14.0  8.5
 80    6    19    0   16.0  8.4
 80    7     2    0   17.0  8.5
 80    7    17    0   20.0  8.5
 80    7    31    0   19.0  8.3
 80    8    18    0   17.0  9.2
 80    8    26    0   22.0  8.5
 80   10    30    0    5.0 11.8
 80   11    13    0    5.0 11.9
```

```
STATION=Q10 POOR FARM BROOK

YEAR MONTH DAY DEPTH TMP  DOX

 80    3     3    0   -0.5 12.7
 80    4     8    0    7.7 11.9
 80    4    24    0    9.4 13.0
 80    5     6    0   16.0 11.3
 80    5    21    0   13.0 10.1
 80    6     2    0   18.0  8.4
 80    6    19    0   16.0  7.6
 80    7     2    0   19.5  8.0
 80    7    17    0   27.0  5.0
 80    7    31    0   22.0  7.0
 80    8    26    0   22.0  5.0
 80   10    30    0    3.0  9.2
 80   11    13    0    0.0 11.7
```

```
STATION=Q11 NEWTON POND OUTLET

YEAR MONTH DAY DEPTH  TMP DOX

 80    3     3    0    1.7 13.3
 80    4     8    0    8.3 11.7
 80    4    24    0   12.2 11.1
 80    5     6    0   17.0 10.3
 80    5    21    0   16.0  7.9
 80    6     2    0   20.0  6.8
 80    6    19    0   21.0  7.6
 80    7     2    0   22.0  7.0
 80    7    17    0   25.0  3.0
 80    7    31    0   22.0  5.3
 80    8    18    0   20.0  6.4
 80    9    16    0   15.0  3.5
 80    9    30    0   12.0  6.9
 80   10    30    0    4.0  8.2
 80   11    13    0    1.0 12.2
```

```
STATION=Q12 LAKE @ LINCOLN ST.

YEAR MONTH DAY DEPTH  TMP DOX

 80    4     8    0    6.1 11.0
 80    4    24    0   11.1 10.9
 80    5     6    0   18.0 10.6
 80    5    21    0   16.0  9.0
 80    6     2    0   21.0  6.7
 80    6    19    0   19.0  2.3
 80    7     2    0   21.0  6.1
 80    7    17    0   27.0  5.6
 80    7    31    0   24.0  3.6
 80    8    18    0   20.0  4.0
 80    8    26    0   22.0  8.7
 80    9    16    0   19.5  9.0
 80    9    30    0   17.0  8.2
 80   10    30    0    4.0  8.8
```

```
STATION=Q12 LAKE @ LINCOLN ST.

YEAR MONTH DAY DEPTH TMP DOX

 80   11   13    0   0.0 12.0
```

```
STATION=Q13 BILLINGS BROOK

YEAR MONTH DAY DEPTH  TMP DOX

 80     3     3   0    1.1 11.8
 80     4     8   0    6.1 10.2
 80     4    24   0   12.2 11.6
 80     5     6   0   17.0 10.3
 80     5    21   0   14.0  7.4
 80     6     2   0   18.0  8.7
 80     6    19   0   19.0  3.2
 80     7     2   0   19.0  5.5
 80     7    17   0   24.0  4.6
 80     7    31   0   22.0  4.5
 80     8    18   0   18.0  6.7
 80     8    26   0   19.0  5.2
 80     9    16   0   14.0  6.3
 80     9    30   0   11.0  7.5
 80    10    30   0    4.0  8.9
 80    11    13   0    1.0 10.5
```

```
STATION=Q15 O HARA BROOK

YEAR MONTH DAY DEPTH  TMP DOX

 80     4     8   0    5.5 12.6
 80     5     6   0   12.0 10.6
 80     5    21   0   12.0 10.0
 80     6     2   0   17.0  7.8
 80     6    19   0   18.0  7.9
 80     7     2   0   17.5  8.5
 80     7    31   0   19.0  8.2
 80    10    30   0    5.0 11.8
 80    11    13   0    4.0 11.5
```

```
STATION=Q16 MEDICAL SCHOOL DRAIN

YEAR MONTH DAY DEPTH  TMP DOX

 80     3     3   0    1.7 13.3
 80     4     8   0    5.5 12.3
 80     4    24   0   10.0 11.6
 80     5     6   0   13.0 11.0
 80     5    21   0   16.0 10.2
 80     6     2   0   16.0 10.1
 80     6    19   0   15.0  9.1
 80     7     2   0   22.0  8.4
 80     7    17   0   24.0  9.0
 80     7    31   0   24.0  8.6
```

```
STATION=Q16 MEDICAL SCHOOL DRAIN

YEAR MONTH DAY DEPTH TMP   DOX

 80    8   18    0   25.0  8.7
 80    8   26    0   25.0  8.8
 80    9   16    0   21.0  9.7
 80    9   30    0   17.0  8.9
 80   10   30    0    5.0  8.9
 80   11   13    0    6.0 11.4
```

```
STATION=Q17 TILLY BROOK

YEAR MONTH DAY DEPTH TMP  DOX

 80     4     8   0      .  11.1
 80     4    24   0   12.2 10.1
 80     5     6   0   17.0  9.0
 80     5    21   0   16.0  8.9
 80     6     2   0   18.0  8.3
 80     6    19   0   20.0  9.8
 80     7     2   0   19.0  8.5
 80     7    17   0   24.0  7.9
 80     7    31   0   22.0  7.4
 80     8    18   0   23.0  8.8
 80     8    26   0   21.0  7.7
 80     9    16   0   17.0  6.8
 80     9    30   0   10.0  7.4
 80    10    30   0    5.0 11.4
 80    11    13   0    3.0 11.9
```

```
STATION=Q18 JORDAN POND OUTLET

YEAR MONTH DAY DEPTH TMP  DOX

 80     4   24    0   10.0 10.0
 80     5    6    0   14.0  9.3
 80     5   21    0   15.0  7.1
 80     7    2    0   22.0  6.7
```

```
STATION=Q19 BELMONT STREET DRAIN

YEAR MONTH DAY DEPTH  TMP DOX

 80     4   24    0    8.8 11.2
 80     5    6    0   13.0 11.3
 80     5   21    0   11.0  9.8
 80     6    2    0   16.0  5.5
 80     6   19    0   18.0  7.0
 80     7    2    0   18.5  7.6
 80     7   17    0   22.0  8.5
 80     7   31    0   22.0  7.0
 80     8   18    0   23.0  9.3
 80     8   26    0   22.0  9.7
 80     9   16    0   17.0  5.4
```

```
STATION=Q19 BELMONT STREET DRAIN

YEAR MONTH DAY DEPTH TMP  DOX

 80    9   30    0   14.0 5.3
 80   10   30    0   10.0 8.6
 80   11   13    0    8.0 8.9
```

```
STATION=Q20 CHANNEL BLW. BELMONT ST. DRAIN

YEAR MONTH DAY DEPTH TMP  DOX

 80    6     2   0   20.5 9.5
 80    6    19   0   22.0 8.7
 80    7     2   0   22.5 9.1
 80    7    17   0   25.0 8.6
 80    8    18   0   25.0 9.0
 80    8    26   0   25.0 9.0
 80    9    16   0   21.0 9.2
 80    9    30   0   17.0 7.8
 80   10    30   0   10.5 7.8
 80   11    13   0    7.0 7.8
```

LAKE QUINSIGAMOND AND FLINT POND ALGAE DATA FOR 1980

LAKE=QUINSIGAMOND   STATION=Q01 LAKE, 600 FT SO. I-290   TYPE=LAKE

YEAR	MONTH	DAY	DEPTH	BGA	DIA	FLA	GRA	TLA	CHL	SEC
80	4	8	0	281.0	5395.2	84.3	28.1	5788.6	6.6	6.5
80	4	24	0	56.2	9441.6	196.7	0.0	9694.5	5.8	5.8
80	5	6	0	84.3	3793.5	168.6	28.1	4074.5	3.3	7.0
80	5	21	0	0.0	1011.6	224.8	0.0	1236.4	4.6	7.5
80	6	2	0	0.0	843.0	34.3	0.0	927.3	3.3	13.0
80	6	19	0	28.1	309.1	28.1	112.4	477.7	2.0	15.2
80	7	2	0	112.4	0.0	168.6	265.3	546.3	2.5	11.0
80	7	17	0	590.1	0.0	112.4	140.5	843.0	3.7	11.2
80	7	31	0	421.5	28.1	112.4	28.1	590.1	3.3	9.9
80	8	18	0	337.2	1433.1	84.3	84.3	1938.9	7.1	6.6
80	8	26	0	421.5	309.1	28.1	56.2	814.9	2.9	11.2
80	9	16	0	.	.	.	.	.	.	7.5
80	9	30	0	505.8	84.3	140.5	56.2	786.8	.	5.3
80	10	30	0	281.0	56.2	224.8	28.1	590.1	5.4	5.3
80	11	13	0	84.3	56.2	140.5	0.0	281.0	5.4	5.3

LAKE=QUINSIGAMOND   STATION=Q02 LAKE, 300 FT NO. RT.9   TYPE=LAKE

YEAR	MONTH	DAY	DEPTH	BGA	DIA	FLA	GRA	TLA	CHL	SEC
80	4	8	0	84.3	8120.9	196.7	0.0	8401.9	7.9	6.5
80	4	24	0	28.1	9048.2	84.3	0.0	9160.6	5.8	5.0
80	5	6	0	140.5	4439.8	112.4	28.1	4720.8	4.1	6.0
80	5	21	0	0.0	1236.4	112.4	56.2	1405.0	7.1	8.0
80	6	2	0	168.6	1461.2	168.6	84.3	1882.7	4.1	11.5
80	6	19	0	56.2	196.7	28.1	28.1	309.1	2.3	11.5
80	7	2	0	140.5	0.0	196.7	56.2	393.4	3.3	7.6
80	7	17	0	281.0	28.1	140.5	28.1	477.7	4.1	9.2
80	7	31	0	786.8	28.1	56.2	112.4	983.5	4.6	9.9
80	8	18	0	590.1	281.0	56.2	140.5	1067.8	5.0	7.2
80	8	26	0	393.4	365.3	28.1	28.1	814.9	2.9	12.5
80	9	16	0	.	.	.	.	.	.	7.5
80	9	30	0	337.2	28.1	0.0	0.0	365.3	.	5.3
80	10	30	0	365.3	0.0	421.5	0.0	786.8	6.6	6.3
80	11	13	0	56.2	449.6	168.6	0.0	674.4	6.6	.

LAKE=QUINSIGAMOND   STATION=Q03 LAKE, 300 FT SO. RT.9   TYPE=LAKE

YEAR	MONTH	DAY	DEPTH	BGA	DIA	FLA	GRA	TLA	CHL	SEC
80	4	8	0	56.2	12448.3	252.9	0.0	12575.4	7.5	6.5
80	4	24	0	196.7	10987.1	309.1	0.0	11492.9	9.5	5.0
80	5	6	0	0.0	2641.4	140.5	0.0	2781.9	3.7	9.0
80	5	21	0	0.0	449.6	168.6	0.0	618.2	10.4	7.0
80	6	2	0	0.0	843.0	28.1	0.0	871.1	5.0	10.6
80	6	19	0	252.9	56.2	28.1	112.4	449.6	3.3	13.8
80	7	2	0	224.8	0.0	28.1	309.1	562.0	3.7	9.2
80	7	17	0	309.1	0.0	168.6	309.1	786.8	5.0	9.2
80	7	31	0	1573.6	843.0	28.1	84.3	2529.0	5.4	7.9
80	8	18	0	983.5	421.5	168.6	140.5	1714.1	7.5	5.9
80	8	26	0	365.3	140.5	56.2	0.0	562.0	2.9	11.9
80	9	16	0	.	.	.	.	.	.	9.2

LAKE QUINSIGAMOND AND FLINT POND ALGAE DATA FOR 1980

LAKE=FLINT   STATION=F01 POND, 800 FT SO. INLET   TYPE=LAKE

YEAR	MONTH	DAY	DEPTH	BGA	DIA	FLA	GRA	TLA	CHL	SEC
80	4	24	0	56.2	6996.9	337.2	0.0	7390.3	6.6	5.0
80	5	6	0	0.0	1657.9	168.6	28.1	1854.6	3.3	8.5
80	5	21	0	0.0	1236.4	252.9	28.1	1517.4	5.4	7.9
80	6	2	0	0.0	1545.5	112.4	0.0	1657.9	3.7	9.2
80	6	19	0	28.1	224.8	252.9	337.2	843.0	1.9	8.3
80	7	17	0	84.3	0.0	84.3	477.7	646.3	7.9	7.2
80	7	31	0	646.3	786.8	309.1	84.3	1826.5	4.9	4.6
80	8	18	0	562.0	730.6	252.9	28.1	1573.6	5.0	6.9
80	8	26	0	84.3	983.5	252.9	0.0	1320.7	2.9	6.6
80	9	16	0	.	.	.	.	.	.	8.5
80	9	30	0	449.6	196.7	56.2	0.0	702.5	.	7.3
80	10	30	0	56.2	365.3	393.4	56.2	871.1	7.5	4.6

LAKE=FLINT   STATION=F03 POND, 2000 FT SO. RT.20   TYPE=LAKE

YEAR	MONTH	DAY	DEPTH	BGA	DIA	FLA	GRA	TLA	CHL	SEC
80	4	8	0	84.3	3737.3	0.0	196.7	4018.3	.	5.2
80	4	24	0	56.2	2753.8	646.3	84.3	3540.6	7.9	3.9
80	5	21	0	0.0	309.1	140.5	0.0	449.6	3.7	7.9
80	6	2	0	56.2	337.2	0.0	84.3	477.7	4.1	9.2
80	6	19	0	56.2	168.6	112.4	140.5	477.7	1.8	6.6
80	7	2	0	84.3	0.0	84.3	112.4	281.0	5.0	6.6
80	7	17	0	281.0	56.2	112.4	252.9	702.5	3.3	6.9
80	7	31	0	505.8	28.1	84.3	56.2	674.4	5.4	5.9
80	8	18	0	84.3	0.0	112.4	56.2	252.9	4.1	5.3
80	8	26	0	281.0	0.0	0.0	196.7	477.7	3.3	7.2
80	9	30	0	309.1	84.3	56.2	393.4	843.0	.	3.9
80	10	30	0	56.2	1910.8	56.2	56.2	2079.4	9.5	4.6

LAKE=FLINT   STATION=F04 POND, 1500 FT WEST IRISH DAM   TYPE=LAKE

YEAR	MONTH	DAY	DEPTH	BGA	DIA	FLA	GRA	TLA	CHL	SEC
80	4	24	0	0.0	3484.4	309.1	0.0	3793.5	3.3	.
80	5	21	0	28.1	252.9	140.5	0.0	421.5	5.4	.
80	6	2	0	0.0	140.5	84.3	28.1	252.9	2.9	.
80	6	19	0	0.0	112.4	28.1	84.3	224.8	0.8	.
80	7	2	0	0.0	0.0	140.5	56.2	196.7	2.9	.
80	7	17	0	28.1	0.0	112.4	28.1	168.6	3.3	.
80	7	31	0	84.3	0.0	224.8	28.1	337.2	2.9	.
80	8	18	0	0.0	0.0	196.7	28.1	224.8	2.5	.
80	8	26	0	0.0	28.1	140.5	28.1	196.7	3.3	.
80	9	30	0	28.1	0.0	0.0	84.3	112.4	.	.
80	10	30	0	0.0	786.8	309.1	28.1	1124.0	4.6	.

LAKE QUINSIGAMOND AND FLINT POND ALGAE DATA FOR 1980

LAKE=QUINSIGAMOND STATION=Q03 LAKE, 300 FT SO. RT.9 TYPE=LAKE

YEAR	MONTH	DAY	DEPTH	BGA	DIA	FLA	GRA	TLA	CHL	SEC
80	9	30	0	365.3	0.0	84.3	84.3	533.9	.	5.3
80	10	30	0	112.4	0.0	168.6	0.0	281.0	4.1	4.6
80	11	13	0	84.3	224.8	168.6	0.0	477.7	4.1	4.6

LAKE=QUINSIGAMOND STATION=Q04 LAKE, 1000 FT NO.BRIDLE PATH STM.DR TYPE=LAKE

YEAR	MONTH	DAY	DEPTH	BGA	DIA	FLA	GRA	TLA	CHL	SEC
80	4	8	0	196.7	7362.2	814.9	56.2	8430.0	7.5	9.0
80	4	24	0	84.3	10453.2	590.1	28.1	11155.7	7.1	5.0
80	5	6	0	84.3	1348.8	252.9	28.1	1714.1	2.9	9.0
80	5	21	0	0.0	1995.1	84.3	28.1	2107.5	6.6	7.0
80	6	2	0	0.0	3905.9	56.2	112.4	4074.5	4.1	14.0
80	6	19	0	84.3	84.3	0.0	196.7	365.3	3.7	15.8
80	7	2	0	112.4	0.0	84.3	168.6	365.3	4.1	12.5
80	7	17	0	871.1	84.3	196.7	196.7	1348.8	7.9	10.5
80	7	31	0	1854.6	1011.6	112.4	84.3	3062.9	7.1	6.6
80	8	18	0	337.2	843.0	84.3	168.6	1433.1	5.0	7.2
80	8	26	0	196.7	843.0	112.4	168.6	1320.7	2.5	11.9
80	9	16	0	.	.	.	.	.	.	8.5
80	9	30	0	309.1	84.3	84.3	28.1	505.8	.	4.6
80	10	30	0	84.3	56.2	449.6	0.0	590.1	8.3	4.6
80	11	13	0	28.1	1011.6	814.9	112.4	1967.0	9.0	5.9

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LAKE QUINSIGAMOND AND FLINT POND PROFILE DATA FOR 1980

LAKE=FLINT   STATION=F01 POND, 800 FT SO. INLET   TYPE=LAKE

YEAR MONTH DAY DEPTH    TSL  SSL CLR  TCF FCF FST RTCF RFCF RFST

 80     4    8     2   126.0 3.0   .    .   .   .
 80     4    8    10   132.0 5.0   .    .   .   .
 80     4   24     0   144.0 2.0   .   10   5   5    K    K    K
 80     4   24    10   146.0 3.0  10    .   .   .
 80     5    6     0   210.0 2.0   .   40   5   5         K    K
 80     5    6    10   204.0 4.5   .    .   .   .
 80     5   21     0   124.0 1.0   .   40  10   5              K
 80     5   21    10   174.0 2.0   .    .   .   .
 80     6    2     0   188.0 1.0  10   20   5   5         K    K
 80     6    2    10   194.0 3.0  40    .   .   .
 80     6   19     0   196.0 2.0  15   10   5   5         K    K
 80     6   19     5   194.0 1.5  15    .   .   .
 80     6   19     8   202.0 2.0  20    .   .   .
 80     7    2     0   236.0 6.0  15   40   5  10         K
 80     7    2     5   200.0 3.0   5    .   .   .
 80     7    2     8   122.0 3.5   5    .   .   .
 80     7   17     0   388.0 2.0  15 1200  10   .         K
 80     7   17     8   272.0 4.5  25    .   .   .
 80     7   31     0    98.0 2.0  25   30   5   5              K
 80     7   31    10   124.0 3.4  35    .   .   .
 80     8   18     0   108.0 2.0  15   20   5   5         K    K
 80     8   18     5   114.0 3.0  25    .   .   .
 80     8   18    10   114.0 3.0  15    .   .   .
 80     8   26     0    62.0 0.5  30   60   5   5         K    K
 80     8   26     5    76.0 1.5  30    .   .   .
 80     8   26    10    66.0 2.0  15    .   .   .
 80     9   16     0   166.0 3.0  35   80  10   5              K
 80     9   16     5   174.0 3.5  30    .   .   .
 80     9   16     7   156.0 6.5  30    .   .   .
 80     9   30     0   152.0 0.5  10   30   5   5         K    K
 80     9   30     5   150.0 1.0   5    .   .   .
 80     9   30    10   152.0 2.0  25    .   .   .
 80    10   30     0   104.0 2.0  35   10   5   5         K    K
 80    10   30     5   112.0 2.0  20    .   .   .
 80    10   30    10    94.0 3.0  30    .   .   .

LAKE=FLINT   STATION=F02 POND, 1500 FT NO. RT.20   TYPE=LAKE

YEAR MONTH DAY DEPTH    TSL  SSL CLR  TCF FCF FST RTCF RFCF RFST

 80     4    8     0   132.0 3.0   .   10   5   .         K
 80     4   24     0   134.0 2.5  10   10   5   5         K    K
 80     5    6     0   150.0 2.0   .  470   5   5              K
 80     5   21     0   130.0 1.0   .  150   5   5              K
 80     6    2     0   182.0 1.0   5   10   5   5         K    K
 80     6   19     0   134.0 0.5  20    5   5   5         K    K
 80     7    2     0   130.0 4.5  30   30  20   5
 80     7   17     0   136.0 3.5  20    .   .   .
 80     7   31     0   126.0 1.5  30   20   5   5         K    K
 80     8   18     0   108.0 1.5  15   40   5   5         K    K
 80     8   26     0    78.0 1.5  25   40   5   5         K    K
 80     9   16     0   156.0 4.5  30   70  10   5         K    K
 80     9   30     0   152.0 2.0   5   10   5   5         K    K
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LAKE QUINSIGAMOND AND FLINT POND PROFILE DATA FOR 1980

LAKE=FLINT   STATION=F02 POND, 1500 FT NO. RT.20   TYPE=LAKE

YEAR MONTH DAY DEPTH    TSL  SSL CLR  TCF FCF FST RTCF RFCF RFST

 80    10   30     0   104.0 2.5  30  140  20   5              K

LAKE=FLINT   STATION=F03 POND, 2000 FT SO. RT.20   TYPE=LAKE

YEAR MONTH DAY DEPTH    TSL  SSL CLR  TCF FCF FST RTCF RFCF RFST

 80     4    8     0       .   .   .   20   5   .         K
 80     4    8     2   136.0 3.5   .    .   .   .
 80     4    8    13   136.0 5.5   .    .   .   .
 80     4   24     0   144.0 3.5  15   10   5   5         K    K
 80     4   24    13   152.0 3.5  20    .   .   .
 80     5    6     0   210.0 1.0   .   10   5   5    K    K    K
 80     5    6    13   230.0 4.5   .    .   .   .
 80     5   21     0   208.0 2.0   .   80   5   5              K
 80     5   21    13   144.0 3.5   .    .   .   .
 80     6    2     0   208.0 0.0  20   10   5   5         K    K
 80     6    2    11   206.0 4.0  20    .   .   .
 80     6   19     0       .   .   .   10   5   5         K    K
 80     6   19     7   212.0 2.0  20    .   .   .
 80     6   19    13   218.0 3.5  35    .   .   .
 80     7    2     0   194.0 0.5  25  110  25   5              K
 80     7    2     7   238.0 2.0  10    .   .   .
 80     7    2    13   222.0 6.0  15    .   .   .
 80     7   17     0   132.0 2.5  15    .   .   .
 80     7   17     8   730.0 3.5  25    .   .   .
 80     7   31     0   138.0 2.0  15   60   5   5         K    K
 80     7   31    13   134.0 2.5  25    .   .   .
 80     8   18     0   132.0 2.0  15   20   5   5         K    K
 80     8   18     7   134.0 2.5  35    .   .   .
 80     8   18    13   130.0 2.5  30    .   .   .
 80     8   26     0    80.0 1.5   5   10   5   5         K    K
 80     6   26     7   124.0 2.0  10    .   .   .
 60     8   26    13   124.0 5.0   5    .   .   .
 80     9   16     0   176.0 8.0  30  160  10   5         K    K
 80     9   16     7   206.0 6.5  20    .   .   .
 80     9   16    13   196.0 7.5  30    .   .   .
 80     9   30     0   154.0 5.0  35    .   .   .
 80     9   30     7   160.0 3.5  15    .   .   .
 80     9   30    13   166.0 5.5  20    .   .   .
 80    10   30     0   114.0 4.5   5   10   5   5         K    K
 80    10   30     7   120.0 5.5  30    .   .   .
 80    10   30    13   110.0 4.0   5    .   .   .
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LAKE QUINSIGAMOND AND FLINT POND PROFILE DATA FOR 1980

LAKE=FLINT   STATION=F04 POND, 1500 FT WEST IRISH DAM   TYPE=LAKE

YEAR	MONTH	DAY	DEPTH	TSL	SSL	CLR	TCF	FCF	FST	RTCF	RFCF	RFST
80	4	8	0	146.0	4.0	.	10	5	.		K	
80	4	24	0	144.0	2.5	20	400	10	20		K	
80	5	6	0	203.0	2.5	.	30	5	5		K	K
80	5	21	0	136.0	3.5	.	120	5	5			K
80	6	2	0	184.0	1.0	25	20	5	5		K	K
80	6	19	0	200.0	1.5	15	10	5	5		K	K
80	7	2	0	134.0	2.0	25	100	15	10			
80	7	17	0	134.0	2.5	25	.	.	.			
80	7	31	0	123.0	1.5	20	.	.	.			
80	8	18	0	124.0	0.5	25	40	5	5		K	K
80	8	26	0	126.0	2.5	35	500	10	.			
80	9	16	0	168.0	4.0	30	270	10	5			K
80	9	30	0	190.0	1.0	5	20	5	5			K
80	10	30	0	98.0	2.0	20	20	5	5		K	K

LAKE=FLINT   STATION=F05 POND, @ RT.20 BRIDGE   TYPE=LAKE

YEAR	MONTH	DAY	DEPTH	TSL	SSL	CLR	TCF	FCF	FST	RTCF	RFCF	RFST
80	4	8	0	148.0	4.0	.	30	5	.		K	
80	4	24	0	146.0	2.5	10	30	5	5		K	K
80	5	6	0	148.0	4.5	.	230	5	5		K	K
80	5	21	0	136.0	3.0	.	200	30	5			K
80	6	2	0	138.0	0.0	20	350	150	5			K
80	6	19	0	136.0	2.5	30	150	50	10			
80	7	2	0	128.0	1.5	25	40	20	5			K
80	7	17	0	132.0	3.5	35	1000	30	.			
80	7	31	0	124.0	4.0	25	240	30	40			
80	8	18	0	130.0	3.5	30	280	160	25			
80	8	26	0	.	.	.	60	20	.			
80	9	16	0	162.0	5.5	30	300	50	5			K
80	9	30	0	172.0	1.5	10	40	10	5			K
80	10	30	0	92.0	3.0	20	120	10	10			

LAKE=FLINT   STATION=F06 SOUTH MEADOW BROOK   TYPE=TRIBUTARY

YEAR	MONTH	DAY	DEPTH	TSL	SSL	CLR	TCF	FCF	FST	RTCF	RFCF	RFST
80	3	3	0	164.0	6.5	.	40	5	.			
80	4	8	0	130.0	2.0	.	5000	180	.			
80	4	24	0	144.0	1.0	15	10	5	5	K	K	
80	5	6	0	156.0	2.0	.	530	25	5			
80	5	21	0	140.0	1.5	.	400	110	10			
80	6	2	0	152.0	1.0	30	2500	200	30			
80	6	19	0	146.0	2.0	30	300	70	30			
80	7	2	0	120.0	5.0	5	500	180	250			
80	7	17	0	676.0	5.5	25	320	90	.			
80	7	31	0	104.0	1.0	60	1200	130	120			
80	8	18	0	144.0	2.5	20	240	60	26			
80	8	26	0	144.0	15.0	20	200	90	.			
80	9	16	0	200.0	9.0	25	400	130	10			
80	9	30	0	184.0	4.0	5	160	30	5			K

LAKE QUINSIGAMOND AND FLINT POND PROFILE DATA FOR 1980

LAKE=FLINT   STATION=F06 SOUTH MEADOW BROOK   TYPE=TRIBUTARY

YEAR	MONTH	DAY	DEPTH	TSL	SSL	CLR	TCF	FCF	FST	RTCF	RFCF	RFST
80	10	30	0	102.0	5.5	35	280	60	20			
80	11	13	0	116.0	1.0	0	200	10	20			

LAKE=FLINT   STATION=F07 INLET FROM LK. QUINS.   TYPE=LAKE

YEAR	MONTH	DAY	DEPTH	TSL	SSL	CLR	TCF	FCF	FST	RTCF	RFCF	RFST
80	3	3	0	158.0	2.0	.	40	5	.			
80	4	8	0	154.0	2.5	.	10	5	.		K	
80	4	24	0	152.0	2.5	20	100	10	5			
80	5	6	0	158.0	2.0	.	10	5	5	K	K	
80	5	21	0	204.0	2.0	.	10	5	5		K	K
80	6	2	0	190.0	0.0	15	30	5	5			K
80	6	19	0	210.0	6.0	15	40	5	5		K	K
80	7	2	0	216.0	2.0	50	150	60	40			
80	7	17	0	200.0	1.0	10	320	90	.			
80	7	31	0	.	.	.	60	20	10			
80	8	18	0	140.0	2.5	15	40	5	5		K	K
80	8	26	0	128.0	2.5	10	80	10	.			
80	9	16	0	226.0	8.0	25	550	10	10			
80	9	30	0	164.0	4.5	25	80	10	5			
80	10	30	0	118.0	5.0	10	140	5	5		K	K
80	11	13	0	108.0	0.0	10	10	5	5		K	K

LAKE=FLINT   STATION=F08 IRISH DAM OUTLET   TYPE=LAKE

YEAR	MONTH	DAY	DEPTH	TSL	SSL	CLR	TCF	FCF	FST	RTCF	RFCF	RFST
80	3	3	0	180.0	0.5	.	60	5	.			
80	4	8	0	142.0	2.5	.	20	5	.		K	
80	4	24	0	142.0	1.0	20	30	5	5		K	K
80	5	6	0	216.0	3.5	.	30	5	5		K	K
80	5	21	0	164.0	3.0	.	10	5	5		K	K
80	6	2	0	230.0	1.5	40	10	5	5		K	K
80	6	19	0	202.0	2.0	25	100	5	80		K	
80	7	2	0	132.0	1.5	10	30	5	15			
80	7	17	0	242.0	3.5	20	20	10	.	K	K	
80	7	31	0	136.0	0.5	15	40	5	5		K	K
80	8	18	0	142.0	1.0	10	200	10	5			K
80	8	26	0	126.0	4.0	35	260	10	.			
80	9	16	0	272.0	6.5	20	200	10	5		K	K
80	9	30	0	170.0	2.0	10	20	5	5			K
80	10	30	0	104.0	2.0	15	20	5	5		K	K
80	11	13	0	102.0	3.0	15	20	5	5		K	K

LAKE QUINSIGAMOND AND FLINT POND PROFILE DATA FOR 1980

LAKE=FLINT   STATION=F09 BONNIE BROOK   TYPE=TRIBUTARY

YEAR	MONTH	DAY	DEPTH	TSL	SSL	CLR	TCF	FCF	FST	RTCF	RFCF	RFST
80	4	24	0	308.0	2.5	15	20	5	5		K	K
80	5	6	0	332.0	6.0	.	200	40	5			
80	5	21	0	284.0	8.0	.	2000	150	5			K
80	6	2	0	354.0	11.0	45	3800	300	30			
80	6	19	0	280.0	4.0	35	600	60	30			
80	7	2	0	254.0	7.0	5	9000	400	180			
80	7	17	0	236.0	15.0	20	300	150	.			
80	7	31	0	280.0	4.5	30	4000	350	100			
80	8	18	0	270.0	5.5	20	2000	80	10			
80	9	16	0	572.0	6.5	10	400	20	30			
80	9	30	0	284.0	7.5	10	560	100	20			
80	10	30	0	224.0	3.5	10	340	50	40			
80	11	13	0	236.0	6.0	10	.	.	.			

LAKE=QUINSIGAMOND   STATION=Q01 LAKE, 600 FT SO. I-290   TYPE=L

YEAR	MONTH	DAY	DEPTH	TSL	SSL	CLR	TCF	FCF	FST	RTCF	RFCF	RFST
80	4	8	0	122.0	3.0	.	160	10	5			K
80	4	8	20	126.0	4.0	.	.	.	.			
80	4	8	90	138.0	2.0	.	.	.	.			
80	4	24	0	116.0	0.0	15	20	5	10		K	K
80	4	24	40	116.0	1.5	20	.	.	.			
80	4	24	85	122.0	1.0	20	.	.	.			
80	5	6	0	134.0	3.0	.	50	5	5			K
80	5	6	20	126.0	2.0	.	.	.	.			
80	5	6	90	136.0	1.5	.	.	.	.			
80	5	21	0	128.0	0.0	20	280	40	5			
80	5	21	20	122.0	0.0	20	.	.	.			
80	5	21	90	140.0	0.0	30	.	.	.			
80	6	2	0	166.0	1.5	5	40	5	5		K	K
80	6	2	20	158.0	0.5	10	.	.	.			
80	6	2	50	120.0	0.0	5	.	.	.			
80	6	2	85	128.0	0.0	35	.	.	.			
80	6	19	0	176.0	0.5	5	40	5	5		K	K
80	6	19	20	178.0	0.0	10	.	.	.			
80	6	19	50	128.0	0.5	15	.	.	.			
80	6	19	85	142.0	3.0	50	.	.	.			
80	7	2	0	204.0	0.5	20	180	20	5			
80	7	2	20	216.0	1.0	0	.	.	.			
80	7	2	50	144.0	1.0	0	.	.	.			
80	7	2	80	144.0	1.5	0	.	.	.			
80	7	17	0	112.0	1.0	15	40	10	20		K	
80	7	17	20	112.0	3.5	20	.	.	.			
80	7	17	50	142.0	3.0	20	.	.	.			
80	7	17	85	80.0	5.5	25	.	.	.			
80	7	31	0	188.0	2.5	5	400	50	5			K
80	7	31	25	132.0	4.0	10	.	.	.			
80	7	31	50	140.0	1.5	10	.	.	.			
80	7	31	90	156.0	3.5	80	.	.	.			
80	8	18	0	18.8	0.0	35	80	30	5			K
80	8	18	20	188.0	1.0	40	.	.	.			
60	8	18	50	144.0	2.5	100	.	.	.			

LAKE QUINSIGAMOND AND FLINT POND PROFILE DATA FOR 1980

LAKE=QUINSIGAMOND   STATION=Q01 LAKE, 600 FT SO. I-290   TYPE=LAKE

YEAR	MONTH	DAY	DEPTH	TSL	SSL	CLR	TCF	FCF	FST	RTCF	RFCF	RFST
80	8	18	85	156.0	2.0	5	.	.	.			
80	8	26	0	184.0	1.5	5	20	5	5		K	K
80	8	26	20	194.0	2.0	25	.	.	.			
80	8	26	50	134.0	2.0	15	.	.	.			
80	9	16	0	244.0	5.0	10	10	10	5		K	K
60	9	16	30	178.0	7.0	20	.	.	.			
80	9	16	50	170.0	5.5	10	.	.	.			
80	9	16	80	212.0	7.5	.	.	.	.			
80	9	30	0	138.0	2.0	10	40	5	5			K
80	9	30	30	144.0	1.0	20	.	.	.			
90	9	30	50	146.0	1.0	10	.	.	.			
80	9	30	85	164.0	5.0	70	.	.	.			
80	10	30	0	112.0	0.5	15	620	60	30			
80	10	30	50	120.0	1.5	5	.	.	.			
80	10	30	90	176.0	4.5	100	.	.	.			
80	11	13	0	118.0	2.0	25	40	5	5		K	K
00	11	13	50	124.0	3.0	30	.	.	.			
80	11	13	80	128.0	2.0	30	.	.	.			

LAKE=QUINSIGAMOND   STATION=Q02 LAKE, 300 FT NO. RT.9   TYPE=LAKE

YEAR	MONTH	DAY	DEPTH	TSL	SSL	CLR	TCF	FCF	FST	RTCF	RFCF	RFST
80	4	8	0	122.0	0.5	20	50	5	5			K
80	4	8	20	128.0	1.0	.	.	.	.			
80	4	8	60	120.0	2.0	.	.	.	.			
80	4	24	0	114.0	1.0	20	20	5	40		K	
80	4	24	40	122.0	1.0	35	.	.	.			
80	4	24	60	126.0	0.0	15	.	.	.			
80	5	6	0	122.0	2.5	.	70	5	5		K	K
80	5	6	30	132.0	3.5	.	.	.	.			
80	5	6	60	136.0	2.0	.	.	.	.			
80	5	21	0	124.0	0.0	20	60	5	5		K	K
80	5	21	20	126.0	0.0	30	.	.	.			
80	5	21	60	128.0	0.0	20	.	.	.			
80	6	2	0	176.0	1.0	20	320	15	5			K
80	6	2	20	178.0	1.5	10	.	.	.			
80	6	2	50	128.0	0.0	10	.	.	.			
80	6	2	60	128.0	0.5	20	.	.	.			
80	6	19	0	184.0	1.0	10	30	5	5			K
80	6	19	20	174.0	1.5	20	.	.	.			
80	6	19	50	136.0	1.5	20	.	.	.			
80	6	19	55	138.0	1.5	35	.	.	.			
80	7	2	0	206.0	2.0	15	450	80	5			
80	7	2	20	196.0	3.0	25	.	.	.			
80	7	2	50	146.0	1.0	5	.	.	.			
80	7	2	55	140.0	2.0	10	.	.	.			
80	7	17	0	60.0	3.5	20	160	20	10			K
80	7	17	20	56.0	4.0	15	.	.	.			
80	7	17	50	54.0	3.0	20	.	.	.			
80	7	17	60	66.0	2.0	15	.	.	.			
80	7	31	0	202.0	2.5	5	480	60	5			
80	7	31	25	138.0	6.0	5	.	.	.			

LAKE QUINSIGAMOND AND FLINT POND PROFILE DATA FOR 1980

LAKE=QUINSIGAMOND   STATION=Q02 LAKE, 300 FT NO. RT.9   TYPE=LAKE

YEAR	MONTH	DAY	DEPTH	TSL	SSL	CLR	TCF	FCF	FST	RTCF	RFCF	RFST
80	7	31	30	156.0	2.5	10	.	.	.			
80	7	31	60	152.0	2.5	25	.	.	.			
80	8	18	0	216.0	2.0	5	60	20	5			K
80	8	18	20	200.0	1.5	25	.	.	.			
80	8	18	50	140.0	0.5	25	.	.	.			
80	8	18	60	150.0	1.5	15	.	.	.			
80	8	26	0	226.0	2.0	5	40	20	5			K
80	8	26	25	150.0	3.0	30	.	.	.			
80	8	26	30	134.0	1.0	30	.	.	.			
80	8	26	55	140.0	1.5	5	.	.	.			
80	9	16	0	258.0	0.5	10	600	20	5			K
80	9	16	30	188.0	5.0	35	.	.	.			
80	9	16	50	168.0	4.5	35	.	.	.			
80	9	16	60	210.0	11.0	.	.	.	.			
80	9	30	0	140.0	3.5	5	200	80	5			K
80	9	30	30	144.0	3.5	10	.	.	.			
80	9	30	50	148.0	3.5	15	.	.	.			
80	9	30	60	150.0	2.0	15	.	.	.			
80	10	30	0	124.0	1.5	15	240	50	20			K
80	10	30	50	126.0	1.5	15	.	.	.			
80	10	30	60	138.0	1.5	25	.	.	.			
80	11	13	0	124.0	3.0	30	60	10	5			K
80	11	13	50	138.0	2.0	15	.	.	.			
80	11	13	65	140.0	3.0	20	.	.	.			

LAKE=QUINSIGAMOND   STATION=Q03 LAKE, 300 FT SO. RT.9   TYPE=LAKE

YEAR	MONTH	DAY	DEPTH	TSL	SSL	CLR	TCF	FCF	FST	RTCF	RFCF	RFST
80	4	8	0	100.0	1.5	.	40	5	5		K	K
80	4	8	20	142.0	2.0	.	.	.	.			
80	4	8	80	142.0	2.0	.	.	.	.			
80	4	24	0	128.0	2.0	15	20	5	10		K	K
80	4	24	40	130.0	1.0	30	.	.	.			
80	4	24	75	136.0	0.0	30	.	.	.			
80	5	6	0	140.0	2.5	.	30	5	5		K	K
80	5	6	20	144.0	3.0	.	.	.	.			
80	5	6	80	156.0	2.1	.	.	.	.			
80	5	21	0	134.0	0.0	25	140	5	5		K	K
80	5	21	20	148.0	0.0	25	.	.	.			
80	5	21	80	198.0	0.5	30	.	.	.			
80	6	2	0	196.0	3.5	15	60	5	5			K
80	6	2	20	194.0	1.0	10	.	.	.			
80	6	2	50	138.0	0.0	10	.	.	.			
80	6	2	80	152.0	0.0	60	.	.	.			
80	6	19	0	186.0	1.5	5	.	.	.			
80	6	19	20	190.0	2.0	10	.	.	.			
80	6	19	50	144.0	1.0	15	.	.	.			
80	6	19	80	160.0	5.0	60	.	.	.			
80	7	2	0	132.0	0.5	30	350	50	5			
80	7	2	20	108.0	0.5	15	.	.	.			
80	7	2	50	146.0	1.5	5	.	.	.			
80	7	2	70	150.0	5.5	10	.	.	.			

LAKE QUINSIGAMOND AND FLINT POND PROFILE DATA FOR 1980

LAKE=QUINSIGAMOND   STATION=Q03 LAKE, 300 FT SO. RT.9   TYPE=LAKE

YEAR	MONTH	DAY	DEPTH	TSL	SSL	CLR	TCF	FCF	FST	RTCF	RFCF	RFST
80	7	17	0	98.0	2.5	15	20	10	10		K	
80	7	17	20	106.0	2.5	15	.	.	.			
80	7	17	50	60.0	2.5	10	.	.	.			
80	7	17	80	146.0	6.0	100	.	.	.			
80	7	31	0	178.0	3.5	10	80	10	5			K
80	7	31	25	138.0	3.5	10	.	.	.			
80	7	31	50	152.0	1.0	20	.	.	.			
80	7	31	75	162.0	2.0	70	.	.	.			
80	8	18	0	198.0	2.5	0	60	30	5			K
80	8	18	20	198.0	2.0	15	.	.	.			
80	8	18	50	154.0	1.0	10	.	.	.			
80	8	18	80	188.0	3.5	100	.	.	.			
80	8	26	0	218.0	1.5	10	60	20	5			K
50	8	26	20	212.0	2.5	40	.	.	.			
80	8	26	50	156.0	1.5	35	.	.	.			
80	8	26	75	194.0	3.0	100	.	.	.			
00	9	16	0	164.0	3.0	10	40	10	5			K
80	9	16	30	178.0	4.0	15	.	.	.			
80	9	16	50	184.0	4.5	45	.	.	.			
80	9	16	75	224.0	1.0	.	.	.	.			
80	9	30	0	138.0	2.5	10	140	10	5			K
80	9	30	30	126.0	3.0	20	.	.	.			
80	9	30	50	166.0	1.5	10	.	.	.			
80	9	30	80	198.0	2.5	60	.	.	.			
80	10	30	0	132.0	1.0	30	230	40	50			
80	10	30	50	146.0	2.0	30	.	.	.			
80	10	30	80	176.0	2.0	90	.	.	.			
80	11	13	0	146.0	3.0	35	20	5	5			K
80	11	13	50	142.0	4.0	35	.	.	.			
80	11	13	80	142.0	3.0	35	.	.	.			

LAKE=QUINSIGAMOND   STATION=Q04 LAKE, 1000 FT NO.BRIDLE PATH STM.DR

YEAR	MONTH	DAY	DEPTH	TSL	SSL	CLR	TCF	FCF	FST	RTCF	RFCF	RFST
80	4	8	0	142.0	3.0	.	10	5	5		K	K
80	4	8	25	168.0	2.0	.	.	.	.			
80	4	8	50	148.0	1.0	.	.	.	.			
80	4	24	0	132.0	3.0	35	10	5	10	K	K	K
80	4	24	30	136.0	1.5	30	.	.	.			
00	4	24	45	134.0	0.0	20	.	.	.			
00	5	6	0	132.0	2.5	.	10	5	5	K	K	K
80	5	6	30	138.0	1.5	.	.	.	.			
80	5	6	50	142.0	2.5	.	.	.	.			
80	5	21	0	204.0	0.0	35	30	5	5		K	K
80	5	21	20	204.0	0.0	20	.	.	.			
80	5	21	50	138.0	1.5	35	.	.	.			
80	6	2	0	182.0	0.0	10	90	5	5		K	K
80	6	2	20	192.0	0.0	10	.	.	.			
80	6	2	50	162.0	0.0	70	.	.	.			
80	6	19	0	188.0	0.5	5	10	5	5			K
80	6	19	20	184.0	1.5	2	.	.	.			
80	6	19	45	176.0	6.0	100	.	.	.			

LAKE QUINSIGAMOND AND FLINT POND PROFILE DATA FOR 1980

LAKE=QUINSIGAMOND   STATION=Q04 LAKE, 1000 FT NO.BRIDLE PATH STM.DR

YEAR	MONTH	DAY	DEPTH	TSL	SSL	CLR	TCF	FCF	FST	RTCF	RFCF	RFST
80	7	2	0	128.0	6.0	35	30	5	5		K	
80	7	2	20	132.0	1.0	50	.	.	.			
80	7	2	45	140.0	2.0	80	.	.	.			
80	7	17	0	108.0	2.5	0	20	10	10	K	K	K
80	7	17	20	104.0	3.5	0	.	.	.			
80	7	17	50	142.0	9.0	100	.	.	.			
80	7	31	0	160.0	3.0	15	10	5	5		K	K
80	7	31	25	142.0	1.0	20	.	.	.			
80	7	31	45	176.0	2.5	50	.	.	.			
80	8	18	0	200.0	1.5	25	10	5	5		K	K
80	8	18	20	200.0	2.5	25	.	.	.			
80	8	18	50	172.0	2.0	70	.	.	.			
80	8	26	0	214.0	1.5	0	20	5	5		K	K
80	8	26	20	210.0	2.5	5	.	.	.			
80	8	26	45	17.8	2.5	100	.	.	.			
80	9	16	0	160.0	4.0	5	10	10	5		K	K
80	9	16	30	194.0	7.5	45	.	.	.			
80	9	16	50	212.0	4.5	.	.	.	.			
80	9	30	0	148.0	2.5	15	20	5	5		K	K
80	9	30	30	152.0	4.5	20	.	.	.			
80	9	30	50	148.0	4.0	2	.	.	.			
80	10	30	0	132.0	1.5	30	10	5	5		K	K
80	10	30	45	140.0	3.5	15	.	.	.			
80	10	30	50	150.0	8.0	40	.	.	.			
80	11	13	0	128.0	2.0	15	10	5	5		K	K
80	11	13	45	140.0	9.0	20	.	.	.			

LAKE=QUINSIGAMOND   STATION=Q05 LAKE @ I-290 BRIDGE   TYPE=LAKE

YEAR	MONTH	DAY	DEPTH	TSL	SSL	CLR	TCF	FCF	FST	RTCF	RFCF	RFST
80	4	8	0	128.0	3.5	.	40	5	5		K	K
80	4	24	0	128.0	2.0	20	20	10	10			K
80	5	6	0	142.0	2.0	.	140	20	5			K
80	5	21	0	108.0	0.0	15	160	25	5			
80	6	2	0	176.0	0.0	20	10	5	5			K
80	6	19	0	190.0	1.0	15	10	5	5		K	K
80	7	2	0	126.0	5.0	10	200	30	5			K
80	7	17	0	96.0	2.5	0	20	10	20			
80	7	31	0	184.0	0.5	5	300	10	10			K
80	8	18	0	198.0	2.0	20	20	10	5			K
80	8	26	0	226.0	0.5	0	10	5	5		K	K
80	9	16	0	23.8	3.0	25	30	20	5			K
80	9	30	0	132.0	3.0	5	90	50	5			K
80	10	30	0	134.0	1.5	20	500	80	60			
80	11	13	0	140.0	3.0	15	40	5	10		K	

LAKE QUINSIGAMOND AND FLINT POND PROFILE DATA FOR 1980

LAKE=QUINSIGAMOND   STATION=Q06 LAKE @ RT.9 BRIDGE   TYPE=LAKE

YEAR	MONTH	DAY	DEPTH	TSL	SSL	CLR	TCF	FCF	FST	RTCF	RFCF	RFST
80	4	8	0	128.0	3.5	.	40	5	5		K	K
80	4	24	0	108.0	1.5	0	20	10	10		K	K
80	5	6	0	114.0	2.5	.	320	20	5			K
80	5	21	0	124.0	0.0	25	90	10	5			K
80	6	2	0	176.0	0.0	15	110	25	5			K
80	6	19	0	18.5	0.5	5	5	5	5		K	K
80	7	2	0	130.0	0.5	10	300	30	5			K
80	7	17	0	114.0	2.5	5	120	20	10			
80	7	31	0	184.0	1.5	5	600	230	20			
80	8	18	0	198.0	2.5	0	60	5	5		K	K
80	8	26	0	222.0	0.5	15	120	40	5			K
80	9	16	0	196.0	5.5	25	380	140	10			
80	9	30	0	132.0	2.0	30	280	160	20			
80	10	30	0	126.0	0.5	25	380	60	30			
80	11	13	0	148.0	4.0	35	60	40	5			K

LAKE=QUINSIGAMOND   STATION=Q08 FITZGERALD BROOK   TYPE=TRIBUTARY

YEAR	MONTH	DAY	DEPTH	TSL	SSL	CLR	TCF	FCF	FST	RTCF	RFCF	RFST
80	3	3	0	168.0	1.5	.	370	15	.			
80	4	8	0	206.0	0.0	.	4000	1200	40			
80	4	24	0	188.0	0.0	5	800	80	30			
80	5	6	0	192.0	1.5	.	1300	300	10			
80	5	21	0	200.0	4.5	20	15000	1000	180			
80	6	2	0	186.0	0.0	10	2000	200	150			
80	6	19	0	230.0	0.0	0	2500	1200	800			
80	7	2	0	200.0	0.0	0	26000	2500	200			
80	7	17	0	214.0	0.5	0	1200	110	400			
80	7	31	0	212.0	0.0	5	42000	4000	900			
80	8	18	0	244.0	0.5	0	13000	1400	20			
80	8	26	0	238.0	0.5	5	2000	220	80			
80	10	30	0	18.6	0.0	0	3100	500	90			
80	11	13	0	222.0	2.0	15	3000	600	50			

LAKE=QUINSIGAMOND   STATION=Q09 COALMINE BROOK   TYPE=TRIBUTARY

YEAR	MONTH	DAY	DEPTH	TSL	SSL	CLR	TCF	FCF	FST	RTCF	RFCF	RFST
80	3	3	0	254.0	0.0	.	1400	625	.			
80	4	8	0	224.0	0.5	.	450	150	30			
80	4	24	0	224.0	0.0	0	1000	130	50			
80	5	6	0	210.0	0.0	.	15000	970	30			
80	5	21	0	218.0	7.5	25	9000	500	60			
80	6	2	0	236.0	0.0	40	3600	400	600			
80	6	19	0	218.0	8.5	10	400	40	10			
80	7	2	0	266.0	7.0	1	34000	3000	380			
80	7	17	0	192.0	2.5	0	12000	1100	430			
80	7	31	0	200.0	0.0	10	38000	3200	1300			
80	8	18	0	204.0	0.5	0	51000	4000	60			
80	8	26	0	224.0	1.0	.	38000	4000	500			
80	10	30	0	218.0	0.0	5	2400	150	160			

LAKE QUINSIGAMOND AND FLINT POND PROFILE DATA FOR 1980

LAKE=QUINSIGAMOND STATION=Q09 COALMINE BROOK TYPE=TRIBUTARY

YEAR	MONTH	DAY	DEPTH	TSL	SSL	CLR	TCF	FCF	FST	RTCF	RFCF	RFST
80	11	13	0	234.0	0.0	0	10	5	5		K	K

LAKE=QUINSIGAMOND STATION=Q10 POOR FARM BROOK TYPE=TRIBUTARY

YEAR	MONTH	DAY	DEPTH	TSL	SSL	CLR	TCF	FCF	FST	RTCF	RFCF	RFST
80	3	3	0	206.0	2.0	.	630	20	.			
80	4	8	0	361.0	1.0	.	240	15	10		K	K
80	4	24	0	152.0	1.0	20	60	5	10			K
80	5	6	0	190.0	0.5	.	340	25	5			
80	5	21	0	164.0	1.5	30	650	55	15			
80	6	2	0	166.0	0.0	35	700	55	10			
80	6	19	0	178.0	3.0	40	300	30	80			
80	7	2	0	158.0	0.5	45	950	150	250			
80	7	17	0	168.0	12.5	25	400	20	100			
80	7	31	0	138.0	8.0	20	22000	1500	480			
80	8	26	0	202.0	15.0	5	1000	40	60			
80	10	30	0	162.0	0.5	25	200	10	210			
80	11	13	0	160.0	4.0	10	800	200	180			

LAKE=QUINSIGAMOND STATION=Q11 NEWTON POND OUTLET TYPE=TRIBUT

YEAR	MONTH	DAY	DEPTH	TSL	SSL	CLR	TCF	FCF	FST	RTCF	RFCF	RFST
80	3	3	0	80.0	1.0	.	10	5	.		K	K
80	4	8	0	66.0	0.0	.	30	5	5		K	K
80	4	24	0	62.0	1.0	20	15	5	10			K
80	5	6	0	84.0	30.0	.	170	15	5			
80	5	21	0	132.0	0.0	30	4000	100	5			
80	6	2	0	76.0	0.0	20	250	75	80			
80	6	19	0	144.0	0.0	15	80	20	5			
80	7	2	0	126.0	0.0	5	220	30	15			
80	7	17	0	106.0	1.5	30	140	30	20			
80	7	31	0	84.0	3.5	10	800	80	20			K
80	8	18	0	94.0	1.0	30	300	60	5			K
80	9	16	0	196.0	3.5	30	200	10	5			K
80	9	30	0	90.0	0.5	0	80	10	5		K	K
80	10	30	0	120.0	0.0	0	100	5	5		K	K
80	11	13	0	104.0	2.0	10	20	5	5			

LAKE=QUINSIGAMOND STATION=Q12 LAKE @ LINCOLN ST. TYPE=LAKE

YEAR	MONTH	DAY	DEPTH	TSL	SSL	CLR	TCF	FCF	FST	RTCF	RFCF	RFST
80	4	8	0	108.0	1.5	.	40	5	5		K	K
80	4	24	0	300.0	0.0	30	40	5	10		K	K
80	5	6	0	314.0	3.5	.	30	5	5		K	K
80	5	21	0	108.0	1.0	30	10	5	5		K	K
80	6	2	0	102.0	0.0	50	10	5	5		K	K
80	6	19	0	182.0	2.0	45	40	20	30			
80	7	2	0	80.0	1.0	10	40	5	10		K	

LAKE QUINSIGAMOND AND FLINT POND PROFILE DATA FOR 1980

LAKE=QUINSIGAMOND STATION=Q12 LAKE @ LINCOLN ST. TYPE=LAKE

YEAR	MONTH	DAY	DEPTH	TSL	SSL	CLR	TCF	FCF	FST	RTCF	RFCF	RFST
80	7	17	0	114.0	4.5	25	400	170	20			
80	7	31	0	32.0	1.5	30	440	30	10			
80	8	18	0	96.0	5.0	25	500	10	5			K
80	8	26	0	202.0	4.0	20	80	20	30			
80	9	16	0	226.0	4.5	5	220	20	40			
80	9	30	0	146.0	1.5	0	180	15	10			
80	10	30	0	84.0	0.0	0	2200	480	120			
80	11	13	0	66.0	2.0	5	30	5	10		K	

LAKE=QUINSIGAMOND STATION=Q13 BILLINGS BROOK TYPE=TRIBUTARY

YEAR	MONTH	DAY	DEPTH	TSL	SSL	CLR	TCF	FCF	FST	RTCF	RFCF	RFST
80	3	3	0	108.0	1.0	.	10	5	.			
80	4	8	0	128.0	2.0	.	20	5	5		K	K
80	4	24	0	108.0	5.0	15	20	5	5		K	K
80	5	6	0	136.0	4.0	.	60	5	5			K
80	5	21	0	146.0	6.5	.	480	50	5			K
80	6	2	0	176.0	0.0	35	600	100	5			K
80	6	19	0	206.0	3.5	30	200	100	30			
80	7	2	0	188.0	8.5	15	280	40	150			
80	7	17	0	134.0	11.5	20	500	110	200			
80	7	31	0	106.0	7.0	15	800	180	80			
80	8	18	0	100.0	3.5	25	300	70	10			
80	8	26	0	150.0	1.5	25	600	40	10			
80	9	16	0	164.0	2.0	10	420	30	50			
80	9	30	0	170.0	2.0	0	100	5	10			
80	10	30	0	176.0	2.5	20	400	10	30			
80	11	13	0	136.0	3.0	0	40	5	20		K	

LAKE=QUINSIGAMOND STATION=Q15 O HARA BROOK TYPE=TRIBUTARY

YEAR	MONTH	DAY	DEPTH	TSL	SSL	CLR	TCF	FCF	FST	RTCF	RFCF	RFST
80	4	8	0	162.0	7.5	.	1200	10	5			K
80	5	6	0	194.0	0.5	.	2700	130	5			
80	5	21	0	186.0	5.5	.	4000	250	20			
80	6	2	0	166.0	1.0	35	18000	1000	480			
80	6	19	0	196.0	0.0	5	1500	300	500			
80	7	2	0	204.0	0.0	5	20000	1500	350			
80	7	31	0	48.0	2.0	5	31000	2000	960			
80	10	30	0	186.0	0.0	25	1200	40	50			
80	11	13	0	136.0	3.0	0	40	5	20		K	

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LAKE QUINSIGAMOND AND FLINT POND PROFILE DATA FOR 1980

LAKE=QUINSIGAMOND STATION=Q16 MEDICAL SCHOOL DRAIN TYPE=TRIBUTAR

YEAR	MONTH	DAY	DEPTH	TSL	SSL	CLR	TCF	FCF	FST	RTCF	RFCF	RFST
80	3	3	0	312.0	2.0	.	220	5	.			
80	4	8	0	138.0	6.0	.	60	5	5		K	K
80	4	24	0	154.0	3.5	40	160	10	10			
80	5	6	0	176.0	2.0	.	170	10	5			K
80	5	21	0	122.0	1.0	.	300	5	10			
80	6	2	0	214.0	5.0	20	1000	10	50			
80	6	19	0	196.0	3.5	10	200	10	80			
80	7	2	0	170.0	5.0	5	700	100	650			
80	7	17	0	186.0	3.5	25	2700	240	460			
80	7	31	0	40.0	6.5	20	1400	200	140			
80	8	18	0	98.0	3.0	10	240	10	5			K
80	8	26	0	202.0	3.0	5	400	60	10			
80	9	16	0	276.0	5.5	15	600	100	10			K
80	9	30	0	178.0	5.0	5	220	80	40			
80	10	30	0	118.0	0.0	20	320	40	60			
80	11	13	0	54.0	3.0	20	320	20	80			

LAKE=QUINSIGAMOND STATION=Q17 TILLY BROOK TYPE=TRIBUTARY

YEAR	MONTH	DAY	DEPTH	TSL	SSL	CLR	TCF	FCF	FST	RTCF	RFCF	RFST
80	4	8	0	94.0	2.0	.	200	5	5		K	K
80	4	24	0	98.0	1.0	35	40	10	5			K
80	5	6	0	94.0	3.0	.	370	5	5		K	K
80	5	21	0	88.0	2.5	.	700	30	5			
80	6	2	0	100.0	1.0	90	2700	200	70			
80	6	19	0	122.0	4.0	70	.	.	.			
80	7	2	0	104.0	2.0	70	6100	280	1300			
80	7	17	0	132.0	8.0	20	240000	20000	230			
80	7	31	0	82.0	3.0	60	21000	1500	600			
80	8	18	0	82.0	2.0	10	10000	900	5			
80	8	26	0	152.0	2.5	40	40000	3500	120			
80	9	16	0	180.0	6.0	15	100000	12000	160			
80	9	30	0	174.0	2.5	10	10000	800	200			
80	10	30	0	104.0	0.0	50	200	10	70			
80	11	13	0	110.0	3.0	45	1000	10	60			

LAKE=QUINSIGAMOND STATION=Q18 JORDAN POND OUTLET TYPE=TRIBUTARY

YEAR	MONTH	DAY	DEPTH	TSL	SSL	CLR	TCF	FCF	FST	RTCF	RFCF	RFST
80	4	24	0	178.0	1.5	10	200	10	5		K	K
80	5	6	0	176.0	0.5	.	170	20	5			
80	5	21	0	112.0	1.0	.	40000	3300	30			
80	7	2	0	104.0	0.5	10	10000	600	700			

LAKE QUINSIGAMOND AND FLINT POND PROFILE DATA FOR 1980

LAKE=QUINSIGAMOND STATION=Q19 BELMONT STREET DRAIN TYPE=TRIBUTARY

YEAR	MONTH	DAY	DEPTH	TSL	SSL	CLR	TCF	FCF	FST	RTCF	RFCF	RFST
80	4	24	0	338.0	2.0	5	5000	600	1000			
80	5	6	0	330.0	3.0	.	40000	6000	4800			
80	5	21	0	320.0	4.0	.	63000	7500	1500			
80	6	2	0	296.0	4.7	90	1500000	10000	1000			
80	6	19	0	334.0	3.7	40	240000	93000	.			
80	7	2	0	238.0	0.0	15	25000	1500	400			
80	7	17	0	200.0	7.5	10	9000	3500	550			
80	7	31	0	142.0	2.1	10	51000	4000	2000			
80	8	18	0	248.0	4.5	15	22000	1400	20			
80	8	26	0	288.0	7.0	5	28000	3000	60			
80	9	16	0	364.0	7.0	5	180000	20000	400			
80	9	30	0	368.0	5.5	5	30000	4000	200			
80	10	30	0	306.0	1.5	15	9000	3000	300			
80	11	13	0	326.0	3.0	0	10000	3000	2000			

LAKE=QUINSIGAMOND STATION=Q20 CHANNEL BLW. BELMONT ST. DRAIN TYPE=

YEAR	MONTH	DAY	DEPTH	TSL	SSL	CLR	TCF	FCF	FST	RTCF	RFCF	RFST
80	5	21	0	180.0	1.0	.	450	35	5			K
80	6	2	0	186.0	0.0	5	400	5	5		K	K
80	6	19	0	190.0	1.5	15	30	5	5			K
80	7	2	0	132.0	1.5	10	450	90	15			
80	7	17	0	138.0	3.5	15	.	.	.			
80	7	31	0	144.0	2.5	20	600	90	36			
80	8	18	0	136.0	1.5	5	60	40	5			K
80	8	26	0	164.0	1.0	10	120	80	5			K
80	9	16	0	152.0	5.0	25	340	90	10			K
80	9	30	0	144.0	3.5	15	.	.	.			
80	10	30	0	108.0	1.0	20	340	50	20			
80	11	13	0	108.0	2.0	10	220	50	20			

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LAKE QUINSIGAMOND AND FLINT POND CHEMICAL DATA FOR 1980

LAKE=FLINT STATION=F01 POND, 800 FT SO. INLET TYPE=LAKE

YEAR	MONTH	DAY	DEPTH	PHU	CND	ALK	HDN	CLD	SO4	IRN	MNG	TLP	TDP	TLN	TKN	ORN	NH3	NO3	INN	SIL
80	4	8	2	7.2	220.0	21.0	44.0	42.00	.	0.00	0.03	0.040	.	1.600	1.200	1.150	0.050	0.400	0.450	2.7
80	4	8	10	7.1	220.0	21.0	44.0	43.00	.	0.00	0.01	0.070	.	1.280	0.880	0.810	0.070	0.400	0.470	1.6
80	4	24	0	7.4	220.0	21.0	43.0	.	16.00	0.02	0.08	0.020	.	1.110	0.710	0.690	0.020	0.400	0.420	2.2
80	4	24	10	7.3	220.0	22.0	45.0	43.00	14.00	0.21	0.07	0.020	.	1.030	0.630	0.600	0.030	0.400	0.430	2.1
80	5	6	0	7.3	210.0	22.0	47.0	41.00	17.00	0.08	0.05	0.010	.	0.820	0.420	0.390	0.030	0.400	0.430	.
80	5	6	10	7.3	210.0	23.0	44.0	42.00	17.00	0.06	0.03	0.010	.	0.940	0.540	0.510	0.030	0.400	0.430	.
80	5	21	0	7.7	200.0	21.0	39.0	39.00	14.00	0.06	0.02	0.030	.	0.740	0.440	0.430	0.010	0.300	0.310	0.9
80	5	21	10	7.6	200.0	22.0	44.0	40.00	14.00	0.03	0.02	0.040	.	0.660	0.360	0.310	0.050	0.300	0.350	0.5
80	6	2	0	7.4	210.0	22.0	42.0	38.00	14.00	0.09	0.07	0.030	0.010	0.520	0.320	0.280	0.040	0.200	0.240	0.0
80	6	2	10	7.3	210.0	23.0	42.0	40.00	14.00	0.08	0.08	0.020	0.010	0.690	0.390	0.310	0.080	0.300	0.380	0.0
80	6	19	0	7.9	220.0	17.0	44.0	37.00	12.00	0.15	0.12	0.070	0.010	0.960	0.860	0.800	0.060	0.100	0.160	0.0
80	6	19	5	7.7	210.0	20.0	42.0	29.00	12.00	0.13	0.10	0.060	0.010	0.820	0.720	0.680	0.040	0.100	0.140	0.0
80	6	19	8	7.5	210.0	19.0	44.0	35.00	12.00	0.06	0.15	0.060	0.010	0.850	0.750	0.680	0.070	0.100	0.170	0.0
80	7	2	0	7.3	200.0	21.0	42.0	40.00	13.00	0.05	0.04	0.060	0.020	0.670	0.570	0.530	0.040	0.100	0.140	3.8
80	7	2	5	7.1	200.0	19.0	42.0	42.00	13.00	0.03	0.02	0.060	0.030	0.640	0.540	0.490	0.050	0.100	0.150	1.2
80	7	2	8	7.4	170.0	18.0	36.0	31.00	10.00	0.13	0.10	0.090	0.020	0.550	0.450	0.350	0.100	0.100	0.200	3.8
80	7	17	0	7.2	190.0	20.0	44.0	38.00	13.00	0.15	0.07	0.020	.	0.470	0.470	0.460	0.010	0.000	0.010	3.6
80	7	17	8	7.0	190.0	22.0	44.0	38.00	13.00	0.15	0.18	0.050	.	0.530	0.520	0.490	0.030	0.010	0.040	2.2
80	7	31	0	7.1	210.0	22.0	43.0	36.00	6.00	0.12	0.06	0.040	0.030	0.620	0.620	0.620	0.000	0.000	0.000	1.4
80	7	31	10	7.3	200.0	22.0	43.0	35.00	7.00	0.15	0.09	0.050	0.030	0.770	0.770	0.770	0.000	0.000	0.000	2.4
80	8	18	0	7.2	200.0	22.0	44.0	39.00	13.00	0.05	0.06	0.040	0.020	0.440	0.440	0.410	0.030	0.000	0.030	2.2
80	8	18	5	7.4	200.0	25.0	42.0	39.00	12.00	0.11	0.12	0.040	0.020	0.390	0.390	0.330	0.060	0.000	0.060	2.8
80	8	18	10	7.2	200.0	19.0	44.0	36.00	11.00	0.08	0.12	0.040	0.040	0.370	0.370	0.320	0.050	0.000	0.050	2.4
80	8	26	0	7.2	200.0	23.0	44.0	37.00	12.00	0.05	0.02	0.020	0.020	0.500	0.300	0.270	0.030	0.200	0.230	1.8
80	8	26	5	7.1	200.0	20.0	44.0	37.00	12.00	0.04	0.02	0.030	0.030	1.130	0.330	0.260	0.070	0.800	0.870	1.4
80	8	26	10	7.4	210.0	25.0	49.0	38.00	13.00	0.05	0.03	0.030	0.030	1.160	0.360	0.300	0.060	0.800	0.860	1.4
80	9	16	0	8.2	200.0	27.0	49.0	41.00	12.00	0.05	0.02	0.070	0.030	0.400	0.400	0.380	0.020	0.000	0.020	1.4
80	9	16	5	8.1	210.0	27.0	49.0	38.00	12.00	0.03	0.02	0.060	0.030	0.630	0.630	0.610	0.020	0.000	0.020	0.5
80	9	16	7	7.9	210.0	30.0	49.0	39.00	12.00	0.06	0.02	0.060	0.050	0.440	0.440	0.410	0.030	0.000	0.030	3.3
80	9	30	0	7.1	210.0	24.0	45.0	39.00	12.00	0.03	0.05	0.080	0.050	0.550	0.550	0.400	0.150	0.000	0.150	2.9
80	9	30	5	7.3	210.0	24.0	49.0	39.00	14.00	0.04	0.06	0.040	0.040	0.910	0.910	0.850	0.060	0.000	0.060	2.8
80	9	30	10	7.2	210.0	24.0	46.0	39.00	13.00	0.05	0.09	0.050	0.040	0.760	0.760	0.700	0.060	0.000	0.060	3.5
80	10	30	0	6.2	200.0	25.0	42.0	39.00	11.00	0.00	0.02	0.050	0.040	0.870	0.770	0.650	0.120	0.100	0.220	3.0
80	10	30	5	6.6	190.0	24.0	47.0	38.00	11.00	0.04	0.01	0.050	0.040	0.860	0.860	0.760	0.100	0.000	0.100	3.7
80	10	30	10	7.0	190.0	24.0	44.0	38.00	12.00	0.00	0.01	0.050	0.030	0.680	0.580	0.470	0.110	0.100	0.210	3.2

LAKE=FLINT STATION=F02 POND, 1500 FT NO. RT 20 TYPE=LAKE

YEAR	MONTH	DAY	DEPTH	PHU	CND	ALK	HDN	CLD	SO4	IRN	MNG	TLP	TDP	TLN	TKN	ORN	NH3	NO3	INN	SIL
80	4	8	0	7.3	210.0	21.0	44.0	42.00	.	0.00	0.02	0.030	.	1.050	0.650	0.580	0.070	0.400	0.470	2.4
80	4	24	0	7.4	210.0	22.0	45.0	43.00	14.00	0.07	0.07	0.040	.	1.200	0.900	0.870	0.030	0.300	0.330	1.9
80	5	6	0	7.5	210.0	22.0	44.0	41.00	17.00	0.06	0.05	0.010	.	0.740	0.440	0.390	0.050	0.300	0.350	.
80	5	21	0	7.6	200.0	24.0	45.0	39.00	13.00	0.07	0.02	0.040	.	0.560	0.360	0.300	0.060	0.200	0.260	2.4
80	6	2	0	7.3	210.0	23.0	42.0	38.00	14.00	0.19	0.10	0.020	0.010	0.480	0.380	0.310	0.070	0.100	0.170	0.0
80	6	19	0	8.0	210.0	22.0	44.0	37.00	12.00	0.08	0.16	0.050	0.010	0.760	0.760	0.700	0.060	0.000	0.060	0.8
80	7	2	0	7.4	190.0	20.0	41.0	36.00	13.00	0.10	0.04	0.090	0.020	0.550	0.450	0.400	0.050	0.100	0.150	3.2
80	7	17	0	7.3	190.0	22.0	44.0	36.00	13.00	0.08	0.13	0.030	.	0.580	0.580	0.570	0.010	0.000	0.010	2.2
80	7	31	0	7.5	200.0	22.0	45.0	35.00	6.00	0.25	0.08	0.040	0.040	0.680	0.680	0.680	0.000	0.000	0.000	1.6
80	8	18	0	7.6	200.0	21.0	42.0	37.00	12.00	0.05	0.09	0.040	0.030	0.370	0.370	0.370	0.000	0.000	0.000	3.2
80	8	26	0	7.2	200.0	22.0	44.0	36.00	11.00	0.05	0.05	0.030	0.020	0.390	0.390	0.380	0.010	0.000	0.010	2.0
80	9	16	0	7.2	210.0	26.0	49.0	38.00	11.00	0.00	0.02	0.050	0.050	0.530	0.530	0.490	0.040	0.000	0.040	0.9
80	9	30	0	7.1	220.0	25.0	49.0	39.00	12.00	0.07	0.06	0.040	0.040	0.900	0.900	0.840	0.060	0.000	0.060	2.8

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. LAKE QUINSIGAMOND AND FLINT POND CHEMICAL DATA FOR 1980

LAKE=FLINT    STATION=F02 POND, 1500 FT NO. RT.20    TYPE=LAKE

YEAR MONTH DAY DEPTH PHU   CND   ALK   HON   CLD    SO4   IRN  MNG   TLP    TDP    TLN   TKN   ORN   NH3   NO3   INN  SIL

 80   10   30    0   7.1 190.0 24.0 44.0 37.00 11.00 0.00 0.02 0.040 0.020 0.670 0.570 0.500 0.070 0.100 0.170 3.3

LAKE=FLINT    STATION=F03 POND, 2000 FT SO. RT.20    TYPE=LAKE

YEAR MONTH DAY DEPTH PHU   CND   ALK   HON   CLD    SO4   IRN  MNG   TLP    TDP    TLN   TKN   ORN   NH3   NO3   INN  SIL

 80    4    8    2   7.4 220.0 21.0 44.0 45.00   .    0.00 0.05 0.020   .   1.500 1.200 1.180 0.020 0.300 0.320 1.6
 80    4    8   13   7.3 220.0 21.0 44.0 44.00   .    0.00 0.06 0.060   .   1.070 0.770 0.740 0.030 0.300 0.330 1.6
 80    4   24    0   7.4 220.0 22.0 45.0 42.00 16.00 0.10 0.11 0.020   .   0.920 0.720 0.670 0.050 0.200 0.250 1.8
 80    4   24   13   7.3 230.0 22.0 45.0 44.00 16.00 0.24 0.17 0.040   .   1.080 0.780 0.710 0.070 0.300 0.370 2.2
 80    5    6    0   7.4 210.0 23.0 44.0 43.00 17.00 0.05 0.05 0.010   .   0.800 0.500 0.470 0.030 0.300 0.330  .
 80    5    6   13   7.4 220.0 24.0 40.0 43.00 17.00 0.07 0.05 0.070   .   0.860 0.560 0.520 0.040 0.300 0.340  .
 80    5   21    0   7.6 210.0 22.0 45.0 44.00 16.00 0.05 0.01 0.030   .   0.540 0.340 0.280 0.060 0.200 0.260 0.6
 80    5   21   13   7.6 210.0 26.0 45.0 44.00 15.00 0.06 0.04 0.060   .   0.630 0.430 0.370 0.060 0.200 0.260 0.7
 80    6    2    0   7.3 220.0 23.0 44.0 43.00 14.00 0.13 0.08 0.030 0.010 0.510 0.310 0.240 0.070 0.200 0.270 0.0
 80    6    2   11   7.4 220.0 24.0 45.0 43.00 14.00 0.09 0.10 0.030 0.010 0.410 0.310 0.210 0.100 0.100 0.200 0.0
 80    6   19    7   7.4 240.0 20.0 44.0 43.00 13.00 0.17 0.58 0.130 0.010 0.870 0.770 0.670 0.100 0.100 0.200 0.0
 80    6   19   13   7.3 240.0 24.0 47.0 43.00 12.00 0.04 0.10 0.100 0.010 0.870 0.770 0.680 0.090 0.100 0.190 0.0
 80    7    2    0   7.4 230.0 25.0 44.0 46.00 14.00 0.09 0.05 0.110 2.000 0.840 0.740 0.620 0.120 0.100 0.220 4.2
 80    7    2    7   7.3 230.0 25.0 44.0 46.00 13.00 0.08 0.03 0.120 0.020 0.880 0.780 0.690 0.090 0.100 0.190 3.8
 80    7    2   13   7.2 230.0 25.0 47.0 46.00 14.00 0.11 0.07 0.140 0.030 0.870 0.770 0.630 0.140 0.100 0.240 2.4
 80    7   17    0   7.7 210.0 28.0 48.0 42.00 14.00 0.08 0.04 0.030   .   0.590 0.590 0.580 0.010 0.000 0.010 1.0
 80    7   17    8   7.3 210.0 26.0 51.0 44.00 14.00 0.18 0.10 0.040   .   0.600 0.600 0.570 0.030 0.000 0.030 2.0
 80    7   31    0   7.6 230.0 28.0 48.0 43.00  6.00 0.05 0.03 0.050 0.040 0.750 0.750 0.750 0.000 0.000 0.000 2.4
 80    7   31   13   7.4 230.0 26.0 49.0 43.00  5.00 0.16 0.04 0.060 0.030 0.620 0.620 0.620 0.000 0.000 0.000 3.0
 80    8   18    0   7.3 220.0 27.0 45.0 42.00 11.00 0.09 0.08 0.040 2.000 0.310 0.310 0.250 0.060 0.000 0.060 3.4
 80    8   18    7   7.4 230.0 28.0 48.0 43.00 12.00 0.13 0.09 0.050 0.030 0.500 0.500 0.450 0.050 0.000 0.050 3.5
 80    8   18   13   7.3 220.0 24.0 48.0 42.00 11.00 0.13 0.07 0.040 0.020 0.450 0.450 0.380 0.070 0.000 0.070 3.3
 80    8   26    0   7.3 220.0 26.0 48.0 39.00 12.00 0.08 0.04 0.020 0.020 0.500 0.300 0.280 0.020 0.200 0.220 2.2
 80    8   26    7   7.1 220.0 20.0 48.0 42.00 10.00 0.12 0.04 0.030 0.030 0.330 0.330 0.320 0.010 0.000 0.010 2.6
 80    8   26   13   7.2 220.0 31.0 48.0 42.00 11.00 0.14 0.04 0.050 0.020 0.450 0.450 0.450 0.000 0.000 0.000 1.8
 80    9   16    0   7.3 240.0 31.0 51.0 44.00 10.00 0.03 0.03 0.050 0.050 0.630 0.630 0.570 0.060 0.000 0.060 0.7
 80    9   16    7   7.3 230.0 31.0 51.0 43.00 11.00 0.04 0.03 0.050 0.040 0.710 0.710 0.650 0.060 0.000 0.060 0.7
 80    9   16   13   7.2 230.0 31.0 51.0 43.00 11.00 0.02 0.01 0.050 0.020 0.620 0.620 0.520 0.100 0.000 0.100 0.6
 80    9   30    0   7.5 240.0 30.0 49.0 42.00 10.00 0.05 0.19 0.050 0.050 0.880 0.880 0.860 0.020 0.000 0.020 3.8
 80    9   30    7   7.4 240.0 30.0 52.0 43.00 10.00 0.02 0.00 0.050 0.050 0.880 0.780 0.620 0.160 0.100 0.260 4.2
 80    9   30   13   7.5 240.0 29.0 52.0 44.00 11.00 0.02 0.01 0.080 0.050 0.870 0.870 0.820 0.050 0.000 0.050 3.9
 80   10   30    0   7.2 210.0 30.0 48.0 41.00  9.00 0.09 0.04 0.050 0.030 0.720 0.720 0.670 0.050 0.000 0.050 3.3
 80   10   30    7   7.3 210.0 25.0 48.0 40.00  9.00 0.10 0.03 0.050 0.040 0.920 0.820 0.760 0.060 0.100 0.160 3.2
 80   10   30   13   7.1 210.0 28.0 48.0 41.00 10.00 0.06 0.03 0.050 0.020 0.610 0.510 0.440 0.070 0.100 0.170 3.8

LAKE=FLINT    STATION=F04 POND, 1500 FT WEST IRISH DAM    TYPE=LAKE

YEAR MONTH DAY DEPTH PHU   CND   ALK   HON   CLD    SO4   IRN  MNG   TLP    TDP    TLN   TKN   ORN   NH3   NO3   INN  SIL

 80    4    8    0   7.3 220.0 22.0 44.0 43.00   .    0.00 0.07 0.050   .   0.940 0.640 0.580 0.060 0.300 0.360 1.1
 80    4   24    0   7.3 220.0 23.0 45.0 44.00 17.00 0.10 0.15 0.020   .   1.150 0.850 0.780 0.070 0.300 0.370 2.0
 80    5    6    0   7.5 210.0 23.0 40.0 41.00 18.00 0.10 0.17 0.050   .   1.060 0.760 0.660 0.100 0.300 0.400  .
 80    5   21    0   7.5 200.0 24.0 45.0 43.00 14.00 0.06 0.07 0.030   .   0.530 0.330 0.260 0.070 0.200 0.270 1.1
 80    6    2    0   7.3 200.0 24.0 43.0 40.00 14.00 0.14 0.08 0.020 0.010 0.500 0.400 0.340 0.060 0.100 0.160 0.0
 80    6   19    0   7.4 230.0 23.0 44.0 41.00 12.00 0.01 0.15 0.100 0.010 0.680 0.680 0.610 0.070 0.000 0.070 0.0
 80    7    2    0   7.3 200.0 23.0 42.0 42.00 12.00 0.06 0.04 0.110 0.020 0.610 0.510 0.450 0.060 0.100 0.160 2.8
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LAKE QUINSIGAMOND AND FLINT POND CHEMICAL DATA FOR 1980

LAKE=FLINT STATION=F04 POND, 1500 FT WEST IRISH DAM TYPE=LAKE

YEAR	MONTH	DAY	DEPTH	PHU	CND	ALK	HDN	CLD	SO4	IRN	MNG	TLP	TDP	TLN	TKN	ORN	NH3	NO3	INN	SIL
80	7	17	0	7.2	210.0	25.0	45.0	41.00	13.00	0.07	0.10	0.040	.	0.470	0.470	0.370	0.100	0.000	0.100	1.6
80	7	31	0	7.5	210.0	25.0	43.0	40.00	6.00	0.13	0.07	0.040	0.020	0.690	0.590	0.590	0.000	0.100	0.100	2.4
80	8	18	0	7.2	210.0	18.0	44.0	40.00	10.00	0.03	0.04	0.030	0.020	0.430	0.430	0.420	0.010	0.000	0.010	3.5
80	8	26	0	7.3	220.0	25.0	48.0	42.00	10.00	0.10	0.05	0.030	0.020	0.360	0.360	0.360	0.000	0.000	0.000	2.8
80	9	16	0	7.6	230.0	30.0	51.0	47.00	11.00	0.02	0.03	0.040	0.020	0.700	0.700	0.680	0.020	0.000	0.020	1.2
80	9	30	0	7.5	270.0	32.0	53.0	53.00	14.00	0.03	0.02	0.050	0.050	0.850	0.850	0.780	0.070	0.000	0.070	2.0
80	10	30	0	7.1	190.0	25.0	44.0	37.00	10.00	0.04	0.03	0.030	0.030	0.590	0.590	0.560	0.030	0.000	0.030	3.0

LAKE=FLINT STATION=F05 POND, @ RT.20 BRIDGE TYPE=LAKE

YEAR	MONTH	DAY	DEPTH	PHU	CND	ALK	HDN	CLD	SO4	IRN	MNG	TLP	TDP	TLN	TKN	ORN	NH3	NO3	INN	SIL
80	4	8	0	7.3	220.0	23.0	48.0	41.00	.	0.00	0.00	0.020	.	1.030	0.630	0.570	0.060	0.400	0.460	1.5
80	4	24	0	7.4	220.0	22.0	45.0	42.00	15.00	0.06	0.07	0.010	.	0.950	0.550	0.500	0.050	0.400	0.450	1.8
80	5	6	0	7.5	210.0	21.0	43.0	40.00	18.00	0.06	0.06	0.040	.	0.950	0.650	0.590	0.060	0.300	0.360	.
80	5	21	0	7.4	200.0	25.0	45.0	38.00	13.00	0.00	0.04	0.040	.	0.560	0.360	0.280	0.080	0.200	0.280	1.5
80	6	2	0	7.4	210.0	24.0	43.0	37.00	13.00	0.06	0.10	0.020	0.010	0.270	0.270	0.190	0.080	0.000	0.080	0.0
80	6	19	0	7.7	210.0	25.0	44.0	37.00	12.00	0.06	0.24	0.100	0.010	0.900	0.900	0.820	0.080	0.000	0.080	1.2
80	7	2	0	7.1	190.0	22.0	34.0	34.00	11.00	0.10	0.03	0.110	0.010	0.580	0.480	0.430	0.050	0.100	0.150	3.8
80	7	17	0	7.0	190.0	22.0	45.0	38.00	14.00	0.15	0.13	0.050	.	0.600	0.600	0.580	0.020	0.000	0.020	2.6
80	7	31	0	7.3	200.0	23.0	43.0	36.00	6.00	0.10	0.07	0.050	0.030	0.950	0.950	0.950	0.000	0.000	0.000	2.2
80	8	18	0	7.2	210.0	23.0	45.0	37.00	10.00	0.07	0.08	0.030	0.010	0.500	0.500	0.460	0.040	0.000	0.040	5.0
80	9	16	0	7.7	220.0	30.0	51.0	43.00	12.00	0.05	0.01	0.060	0.040	0.660	0.660	0.610	0.050	0.000	0.050	0.9
80	9	30	0	7.4	240.0	24.0	48.0	35.00	12.00	0.00	0.00	0.040	0.040	0.630	0.630	0.580	0.050	0.000	0.050	4.3
80	10	30	0	7.1	180.0	28.0	35.0	35.00	10.00	0.10	0.03	0.040	0.030	0.660	0.660	0.630	0.030	0.000	0.030	4.1

LAKE=FLINT STATION=F06 SOUTH MEADOW BROOK TYPE=TRIBUTARY

YEAR	MONTH	DAY	DEPTH	PHU	CND	ALK	HDN	CLD	SO4	IRN	MNG	TLP	TDP	TLN	TKN	ORN	NH3	NO3	INN	SIL
80	3	3	0	6.7	240.0	26.0	63.0	42.00	21.00	0.22	0.07	0.050	.	2.700	0.800	0.700	0.100	1.900	2.000	.
80	4	8	0	7.0	190.0	22.0	48.0	30.00	.	0.00	0.03	0.020	.	1.520	0.620	0.600	0.020	0.900	0.920	8.5
80	4	24	0	7.1	220.0	25.0	55.0	42.00	19.00	0.17	0.07	0.030	.	1.890	0.690	0.550	0.140	1.200	1.340	8.0
80	5	6	0	7.5	210.0	28.0	49.0	34.00	22.00	0.17	0.03	0.040	.	1.770	0.770	0.730	0.040	1.000	1.040	.
80	5	21	0	7.1	210.0	29.0	55.0	34.00	16.00	0.21	0.05	0.040	.	1.300	0.300	0.260	0.040	1.000	1.040	8.3
80	6	2	0	7.4	210.0	23.0	55.0	36.00	16.00	0.23	0.02	0.070	0.010	1.580	0.380	0.300	0.080	1.200	1.280	9.0
80	6	19	0	7.3	220.0	28.0	48.0	34.00	13.00	0.53	0.17	0.100	0.020	2.140	0.840	0.760	0.080	1.300	1.380	11.0
80	7	2	0	7.1	150.0	25.0	18.0	18.00	14.00	0.56	0.08	0.270	0.060	1.900	1.300	1.200	0.100	0.600	0.700	1.1
80	7	17	0	6.7	210.0	27.0	58.0	35.00	16.00	0.45	0.05	0.110	.	1.660	0.560	0.520	0.040	1.100	1.140	8.8
80	7	31	0	6.7	150.0	21.0	38.0	20.00	11.00	0.60	0.08	0.070	0.050	1.100	0.800	0.780	0.020	0.300	0.320	3.8
80	8	18	0	7.1	220.0	26.0	57.0	37.00	15.00	0.10	0.11	0.050	0.020	1.910	0.510	0.450	0.060	1.400	1.460	5.0
80	8	26	0	7.0	220.0	18.0	59.0	37.00	14.00	0.23	0.05	0.190	0.030	2.500	1.400	1.350	0.050	1.100	1.150	4.8
80	9	16	0	7.0	250.0	30.0	61.0	43.00	15.00	0.15	0.03	0.060	0.030	1.810	0.810	0.660	0.150	1.000	1.150	1.2
80	9	30	0	6.9	220.0	26.0	52.0	44.00	14.00	0.08	0.00	0.050	0.050	1.980	0.680	0.590	0.090	1.300	1.390	9.9
80	10	30	0	6.6	180.0	22.0	51.0	29.00	17.00	0.16	0.01	0.050	0.040	1.230	0.530	0.500	0.030	0.700	0.730	1.4
80	11	13	0	6.7	220.0	27.0	54.0	33.00	18.00	0.09	0.01	0.240	0.040	3.500	2.000	1.960	0.040	1.500	1.540	12.0

LAKE QUINSIGAMOND AND FLINT POND CHEMICAL DATA FOR 1980

LAKE=FLINT   STATION=F07 INLET FROM LK. QUINS.   TYPE=LAKE

YEAR	MONTH	DAY	DEPTH	PHU	CND	ALK	HDN	CLD	SO4	IRN	MNG	TLP	TDP	TLN	TKN	ORN	NH3	NO3	INN	SIL
80	3	3	0	7.0	250.0	23.0	51.0	56.00	18.00	0.26	0.11	0.050	.	1.050	0.750	0.680	0.070	0.300	0.370	.
80	4	8	0	7.2	230.0	22.0	48.0	46.00	.	0.00	0.04	0.050	.	1.700	1.300	1.240	0.060	0.400	0.460	1.8
80	4	24	0	7.5	220.0	23.0	49.0	35.00	15.00	0.10	0.11	0.010	.	1.150	0.750	0.710	0.040	0.400	0.440	3.6
80	5	6	0	7.5	210.0	23.0	43.0	43.00	17.00	0.00	0.02	0.040	.	0,870	0.470	0.440	0.030	0.400	0.430	.
80	5	21	0	7.6	210.0	21.0	47.0	43.00	14.00	0.02	0.03	.	.	0.600	0.300	0.250	0.050	0.300	0.350	1.1
80	6	2	0	7.4	210.0	22.0	44.0	38.00	14.00	0.07	0.05	0.020	0.010	0.420	0.420	0.370	0.050	0.000	0.050	0.0
80	6	19	0	7.7	230.0	23.0	44.0	41.00	10.00	0.02	0.10	0.100	0.010	1.080	0.880	0.810	0.070	0.200	0.270	0.0
80	7	2	0	7.2	220.0	22.0	38.0	38.00	13.00	0.10	0.03	0.060	0.020	0.680	0.480	0.410	0.070	0.200	0.270	0.0
80	7	17	0	7.3	210.0	21.0	44.0	35.00	14.00	0.45	0.05	0.110	.	0.690	0.590	0.560	0.030	0.100	0.130	1.0
80	8	18	0	7.3	210.0	22.0	44.0	43.00	10.00	0.16	0.11	0.010	0.010	0.670	0.670	0.640	0.030	0.000	0.030	2.5
80	8	26	0	7.4	220.0	24.0	44.0	41.00	12.00	0.04	0.03	0.030	0.010	2.450	0.450	0.200	0.250	2.000	2.250	4.6
80	9	16	0	7.3	290.0	27.0	59.0	56.00	19.00	0.15	0.06	0.080	0.030	1.090	0.790	0.720	0.070	0.300	0.370	1.2
80	9	30	0	7.3	230.0	27.0	49.0	53.00	13.00	0.03	0.04	0.030	0.030	1.010	0.910	0.840	0.070	0.100	0.170	3.8
80	10	30	0	7.1	210.0	26.0	44.0	39.00	10.00	0.02	0.02	0.050	0.040	0.770	0.670	0.560	0.110	0.100	0.210	4.4
80	11	13	0	7.3	215.0	26.0	44.0	40.00	11.00	0.09	0.08	0.140	0.040	1.800	1.600	1.410	0.190	0.200	0.390	3.6

LAKE=FLINT   STATION=F08 IRISH DAM OUTLET   TYPE=LAKE

YEAR	MONTH	DAY	DEPTH	PHU	CND	ALK	HDN	CLD	SO4	IRN	MNG	TLP	TDP	TLN	TKN	ORN	NH3	NO3	INN	SIL
80	3	3	0	6.8	290.0	39.0	64.0	54.00	21.00	0.26	0.53	0.060	.	1.300	1.000	0.750	0.250	0.300	0.550	.
80	4	8	0	7.0	210.0	21.0	45.0	38.00	.	0.00	0.05	0.030	.	1.140	0.840	0.780	0.060	0.300	0.360	1.6
80	4	24	0	7.4	220.0	22.0	45.0	48.00	15.00	0.10	0.14	0.050	.	1.500	1.200	1.110	0.090	0.300	0.390	1.0
80	5	6	0	7.5	210.0	24.0	40.0	39.00	17.00	0.06	0.12	0.030	.	0.850	0.550	0.480	0.070	0.300	0.370	.
80	5	21	0	7.4	210.0	25.0	44.0	41.00	14.00	0.04	0.06	0.040	.	0.670	0.470	0.340	0.130	0.200	0.330	0.8
80	6	2	0	7.3	210.0	24.0	43.0	41.00	13.00	0.09	0.11	0.050	0.010	0.970	0.370	0.170	0.200	0.600	0.800	0.0
80	6	19	0	7.4	230.0	27.0	44.0	43.00	12.00	0.37	0.17	0.090	0.010	0.870	0.870	0.820	0.050	0.000	0.050	0.0
80	7	2	0	7.3	210.0	25.0	37.0	37.00	13.00	0.06	0.02	0.080	0.030	0.570	0.470	0.400	0.070	0.100	0.170	2.8
80	7	17	0	7.4	210.0	28.0	45.0	44.00	14.00	0.06	0.06	0.060	.	0.790	0.790	0.750	0.040	0.000	0.040	1.0
80	7	31	0	7.4	215.0	25.0	43.0	39.00	9.00	0.13	0.04	0.050	0.030	0.700	0.700	0.700	0.000	0.000	0.000	3.2
80	8	18	0	7.2	220.0	24.0	45.0	45.00	10.00	0.05	0.07	0.020	0.160	0.600	0.500	0.490	0.010	0.100	0.110	2.0
80	8	26	0	7.3	220.0	15.0	45.0	42.00	11.00	0.05	0.12	0.040	0.020	2.140	0.840	0.770	0.070	1.300	1.370	2.2
80	9	16	0	7.2	280.0	29.0	54.0	55.00	12.00	0.07	0.06	0.060	0.030	0.820	0.720	0.690	0.030	0.100	0.130	0.6
80	9	30	0	7.3	270.0	29.0	51.0	53.00	14.00	0.00	0.02	0.030	0.030	0.620	0.620	0.590	0.030	0.000	0.030	1.1
80	10	30	0	7.3	190.0	25.0	44.0	37.00	10.00	0.03	0.00	0.030	0.020	0.410	0.410	0.400	0.010	0.000	0.010	2.7
80	11	13	0	7.4	210.0	27.0	43.0	39.00	12.00	0.05	0.02	0.080	0.030	1.400	1.300	1.220	0.080	0.100	0.180	2.5

LAKE=FLINT   STATION=F09 BONNIE BROOK   TYPE=TRIBUTARY

YEAR	MONTH	DAY	DEPTH	PHU	CND	ALK	HDN	CLD	SO4	IRN	MNG	TLP	TDP	TLN	TKN	ORN	NH3	NO3	INN	SIL
80	4	24	0	7.2	490.0	25.0	72.0	41.00	22.00	0.54	0.21	0.020	.	1.420	0.820	0.760	0.060	0.600	0.660	9.9
80	5	6	0	7.7	500.0	29.0	63.0	110.00	25.00	0.70	0.35	0.020	.	1.130	0.530	0.420	0.110	0.600	0.710	.
80	5	21	0	7.2	480.0	29.0	71.0	115.00	20.00	0.43	0.07	0.050	.	0.880	0.380	0.270	0.110	0.500	0.610	11.0
80	6	2	0	7.2	420.0	27.0	62.0	70.00	21.00	0.79	0.27	0.050	0.030	0.210	0.210	0.090	0.120	0.000	0.120	7.0
80	6	19	0	7.6	460.0	30.0	69.0	87.00	24.00	0.33	0.31	0.070	0.020	1.330	0.830	0.730	0.100	0.500	0.600	9.2
80	7	2	0	7.5	440.0	31.0	66.0	100.00	22.00	0.52	0.09	0.150	0.050	1.140	0.740	0.640	0.100	0.400	0.500	6.8
80	7	17	0	7.1	385.0	28.0	69.0	91.00	26.00	0.65	0.18	0.050	.	0.700	0.500	0.470	0.030	0.200	0.230	6.0
80	7	31	0	6.9	450.0	26.0	68.0	110.00	11.00	0.80	0.23	0.050	0.030	1.070	0.770	0.730	0.040	0.300	0.340	8.2
80	8	18	0	7.3	410.0	30.0	76.0	84.00	27.00	0.20	0.12	0.030	0.040	0.950	0.650	0.630	0.020	0.300	0.320	6.0
80	9	16	0	7.7	770.0	53.0	110.0	115.00	93.00	0.08	0.02	0.060	0.040	13.770	0.770	0.740	0.030	13.000	13.030	1.2
80	9	30	0	7.3	410.0	43.0	77.0	65.00	36.00	0.07	0.00	0.040	0.040	1.630	0.930	0.900	0.030	0.700	0.730	6.2

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LAKE QUINSIGAMOND AND FLINT POND CHEMICAL DATA FOR 1980

LAKE=FLINT    STATION=F09 BONNIE BROOK    TYPE=TRIBUTARY

YEAR MONTH DAY DEPTH PHU  CND   ALK  HDN   CLD    SO4   IRN  MNG   TLP   TDP   TLN   TKN   ORN   NH3   NO3   INN  SIL

 80   10   30    0   7.1 400.0 29.0 79.0 87.00 27.00 0.19 0.21 0.040 0.040 0.980 0.680 0.650 0.030 0.300 0.330 9.6
 80   11   13    0   7.5 420.0 29.0 70.0 90.00 29.00 0.09 0.04 0.080 0.030 1.500 0.900 0.830 0.070 0.600 0.670 8.5

LAKE=QUINSIGAMOND   STATION=Q01 LAKE, 600 FT SO. I-290   TYPE=LAKE

YEAR MONTH DAY DEPTH PHU  CND   ALK  HDN   CLD    SO4    IRN  MNG   TLP   TDP   TLN   TKN   ORN   NH3   NO3   INN  SIL

 80    4    8    0   7.3 210.0 20.0 44.0 41.00   .     0.00 0.04 0.020   .   1.350 0.950 0.830 0.120 0.400 0.520 1.5
 80    4    8   20   7.3 200.0 21.0 44.0 42.00   .     0.13 0.04 0.020   .   1.340 0.940 0.860 0.080 0.400 0.480 2.3
 80    4    8   90   7.3 210.0 21.0 44.0 37.00   .     0.00 0.13 0.010   .   1.280 0.880 0.750 0.130 0.400 0.530 2.4
 80    4   24    0   7.3 200.0 20.0 42.0 38.00 15.00   0.07 0.00 0.030   .   1.110 0.710 0.680 0.030 0.400 0.430 1.8
 80    4   24   40   7.3 200.0 20.0 42.0 40.00 16.00   0.05 0.08 0.070   .   2.000 1.600 1.490 0.110 0.400 0.510 3.1
 80    4   24   85   7.1 200.0 22.0 42.0 39.00 15.00   0.08 0.32 0.040   .   1.220 0.820 0.610 0.210 0.400 0.610 2.6
 80    5    6    0   7.2 190.0 20.0 39.0 36.00 14.00   0.10 0.03 0.050   .   0.950 0.550 0.540 0.010 0.400 0.410  .
 80    5    6   20   7.5 190.0 20.0 39.0 37.00 13.00   0.02 0.02 0.030   .   0.850 0.450 0.430 0.020 0.400 0.420  .
 80    5    6   90   7.1 210.0 25.0 43.0 40.00 13.00   0.25 1.00 0.040   .   1.080 0.680 0.340 0.340 0.400 0.740  .
 80    5   21    0   7.1 180.0 20.0 42.0 37.00 14.00   0.09 0.02 0.050   .   0.830 0.530 0.490 0.040 0.300 0.340 0.9
 80    5   21   20   7.1 180.0 20.0 42.0 40.00 13.00   0.10 0.07 0.050   .   0.800 0.400 0.350 0.050 0.400 0.450 0.5
 80    5   21   90   6.9 200.0 29.0 44.0 41.00 13.00   1.00 1.40 0.070   .   1.170 0.870 0.360 0.510 0.300 0.810 2.9
 80    6    2    0   7.3 190.0 21.0 42.0 39.00 12.00   0.06 0.02 0.040 0.000 0.870 0.570 0.560 0.010 0.300 0.310 0.0
 80    6    2   20   7.2 190.0 21.0 42.0 37.00 15.00   0.00 0.01 0.040 0.000 0.630 0.330 0.300 0.030 0.300 0.330 0.4
 80    6    2   50   6.9 210.0 26.0 42.0 37.00 12.00   0.19 0.50 0.030 0.000 0.920 0.520 0.240 0.280 0.400 0.680 3.0
 80    6    2   85   6.9 210.0 29.0 42.0 40.00 14.00   1.00 1.40 0.050 0.010 1.100 0.700 0.150 0.550 0.400 0.950 4.0
 80    6   19    0   7.5 210.0 20.0 41.0 33.00 14.00   0.07 0.02 0.050 0.010 1.480 1.180 1.140 0.040 0.300 0.340 0.0
 80    6   19   20   7.2 200.0 21.0 41.0 35.00 13.00   0.28 0.08 0.010 0.010 0.850 0.550 0.510 0.040 0.300 0.340 0.0
 80    6   19   50   6.9 220.0 20.0 41.0 38.00 13.00   0.44 0.68 0.010 0.010 1.020 0.620 0.330 0.290 0.400 0.690 2.2
 80    6   19   85   7.0 230.0 27.0 40.0 36.00 14.00   1.30 1.30 0.010 0.010 1.170 0.870 0.250 0.620 0.300 0.920 3.4
 80    7    2    0   7.3 200.0 21.0 38.0 45.00 13.00   0.10 0.01 0.080 0.030 0.740 0.440 0.360 0.080 0.300 0.380 1.6
 80    7    2   20   7.2 200.0 21.0 41.0 34.00 13.00   0.04 0.01 0.050 0.020 0.740 0.440 0.360 0.080 0.300 0.380 1.6
 80    7    2   50   7.7 210.0 25.0 42.0 33.00 13.00   0.50 0.67 0.120 0.030 1.100 0.600 0.390 0.210 0.500 0.710 4.6
 80    7    2   80   7.4 210.0 24.0 42.0 39.00 13.00   1.00 0.90 0.090 0.040 1.030 0.730 0.300 0.430 0.300 0.730 4.2
 80    7   17    0   7.1 190.0 23.0 39.0 36.00 13.00   0.08 0.01 0.010 0.010 0.560 0.360 0.350 0.010 0.200 0.210 0.4
 80    7   17   20   7.1 190.0 20.0 42.0 37.00 13.00   0.08 0.04 0.010 0.010 0.560 0.360 0.340 0.020 0.200 0.220 0.0
 80    7   17   50   6.7 200.0 25.0 42.0 39.00 13.00   0.63 0.74 0.010 0.010 0.860 0.260 0.170 0.090 0.600 0.690 2.6
 80    7   17   85   6.5 210.0 30.0 42.0 39.00 18.00   2.90 1.50 0.080 0.080 1.080 0.980 0.350 0.630 0.100 0.730 3.4
 80    7   31    0   7.2 200.0 20.0 43.0 38.00  4.00   0.12 0.02 0.370 0.050 0.360 0.260 0.260 0.000 0.100 0.100 1.2
 80    7   31   25   7.2 200.0 21.0 44.0 38.00  6.00   0.06 0.03 0.490 0.040 0.640 0.440 0.430 0.010 0.200 0.210 2.8
 80    7   31   50   6.7 210.0 23.0 44.0 39.00  6.00   0.70 0.84 0.340 0.040 0.960 0.260 0.150 0.110 0.700 0.810 4.0
 80    7   31   90   6.8 220.0 31.0 48.0 37.00 13.00   4.80 1.90 0.380 0.030 1.200 1.100 0.240 0.860 0.100 0.960 0.2
 80    8   18    0   6.9 190.0 17.0 44.0 35.00 12.00   0.05 0.00 0.240 0.020 0.590 0.590 0.580 0.010 0.000 0.010 0.6
 80    8   18   20   7.1 190.0 20.0 44.0 36.00 13.00   0.06 0.02 0.370 0.040 0.830 0.830 0.820 0.010 0.000 0.010 0.6
 80    8   18   50   6.8 210.0 28.0 47.0 39.00 11.00   1.50 1.10 0.160 0.160 1.040 0.540 0.380 0.160 0.500 0.660 2.4
 80    8   18   85   6.8 220.0 43.0 48.0 40.00  9.00   6.10 2.40 0.430 0.130 1.600 1.600 1.430 0.170 0.000 0.170 4.3
 80    8   26    0   7.2 190.0 22.0 42.0 36.00 12.00   0.03 0.00 0.010 0.010 2.380 0.380 0.350 0.030 2.000 2.030 0.2
 80    8   26   20   7.4 190.0 22.0 42.0 34.00 14.00   0.02 0.00 0.020 0.010 0.480 0.380 0.370 0.010 0.100 0.110 0.2
 80    8   26   50   7.1 200.0 21.0 44.0 38.00 12.00   0.55 1.00 0.030 0.010 0.970 0.470 0.270 0.200 0.500 0.700 3.4
 80    9   16    0   7.1 200.0 25.0 45.0 38.00 11.00   0.06 0.02 0.100 0.030 0.360 0.360 0.350 0.010 0.000 0.010 0.9
 80    9   16   30   6.9 210.0 33.0 48.0 38.00 12.00  12.00 0.22 0.040 0.020 0.980 0.580 0.480 0.100 0.400 0.500 4.0
 80    9   16   50   6.7 210.0 29.0 48.0 38.00  8.00   0.52 1.50 0.050 0.020 0.760 0.460 0.160 0.300 0.300 0.600 5.3
 80    9   16   80   6.9 240.0 56.0 51.0 39.00  4.00  13.00 3.30 0.460 0.280 2.000 1.900 0.000 1.900 0.100 2.000 8.5
 80    9   30    0   8.3 210.0 33.0 44.0 39.00 13.00   0.06 0.01 0.090 0.030 0.530 0.530 0.520 0.010 0.000 0.010 1.5
 80    9   30   30   7.3 210.0 23.0 44.0 39.00 12.00   0.00 0.02 0.090 0.030 0.590 0.490 0.450 0.040 0.100 0.140 1.8
 80    9   30   50   6.8 220.0 28.0 45.0 39.00 10.00   0.37 1.40 0.100 0.010 0.800 0.500 0.220 0.280 0.300 0.580 5.2
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LAKE QUINSIGAMOND AND FLINT POND CHEMICAL DATA FOR 1980

LAKE=QUINSIGAMOND STATION=Q01 LAKE, 600 FT SO. I-290 TYPE=LAKE

YEAR	MONTH	DAY	DEPTH	PHU	CND	ALK	HDN	CLD	SO4	IRN	MNG	TLP	TDP	TLN	TKN	ORN	NH3	NO3	INN	SIL
80	9	30	85	6.9	220.0	50.0	48.0	39.00	6.00	8.10	2.60	0.280	0.220	1.700	1.600	0.100	1.500	0.100	1.600	8.1
80	10	30	0	7.2	190.0	23.0	44.0	37.00	11.00	0.00	0.02	0.030	0.010	0.860	0.560	0.500	0.060	0.300	0.360	2.2
80	10	30	50	6.7	210.0	31.0	47.0	37.00	9.00	0.20	1.30	0.040	0.010	0.960	0.860	0.440	0.420	0.100	0.520	4.8
80	10	30	90	6.7	240.0	57.0	54.0	39.00	4.00	16.00	3.20	0.400	0.340	2.600	2.600	0.000	2.600	0.000	2.600	10.0
80	11	13	0	7.3	210.0	27.0	47.0	39.00	11.00	0.49	0.38	0.280	0.040	1.700	1.600	1.340	0.260	0.100	0.360	3.6
80	11	13	50	6.9	200.0	26.0	44.0	38.00	10.00	0.32	0.56	0.260	0.030	1.400	1.300	1.040	0.260	0.100	0.360	4.2
80	11	13	80	7.1	210.0	27.0	44.0	38.00	11.00	0.53	0.59	0.150	0.040	1.300	1.200	1.000	0.200	0.100	0.300	3.6

LAKE=QUINSIGAMOND STATION=Q02 LAKE, 300 FT NO. RT.9 TYPE=LAKE

YEAR	MONTH	DAY	DEPTH	PHU	CND	ALK	HDN	CLD	SO4	IRN	MNG	TLP	TDP	TLN	TKN	ORN	NH3	NO3	INN	SIL
80	4	8	0	7.3	200.0	19.0	42.0	40.00	16.00	0.00	0.05	0.010	.	0.490	0.090	0.020	0.070	0.400	0.470	2.0
80	4	8	20	7.5	210.0	20.0	44.0	40.00	.	0.00	0.10	0.010	.	1.600	1.200	1.110	0.090	0.400	0.490	2.3
80	4	8	60	7.5	210.0	21.0	44.0	44.00	.	0.00	0.07	0.040	.	1.360	0.960	0.840	0.120	0.400	0.520	2.5
80	4	24	0	7.4	130.0	19.0	42.0	33.00	16.00	0.07	0.07	0.030	.	1.180	0.780	0.770	0.010	0.400	0.410	1.7
80	4	24	40	7.1	200.0	20.0	42.0	39.00	15.00	0.06	0.04	0.030	.	1.400	1.000	0.920	0.080	0.400	0.480	1.4
80	4	24	60	7.1	210.0	20.0	43.0	39.00	15.00	0.05	0.13	0.050	.	1.400	1.000	0.850	0.150	0.400	0.550	2.8
80	5	6	0	7.3	190.0	19.0	39.0	35.00	11.00	0.05	0.02	0.030	.	0.940	0.540	0.520	0.020	0.400	0.420	.
80	5	6	30	7.3	190.0	20.0	42.0	24.00	13.00	0.03	0.02	0.020	.	0.860	0.460	0.420	0.040	0.400	0.440	.
80	5	6	60	7.2	200.0	22.0	42.0	37.00	12.00	0.03	0.20	0.020	.	1.020	0.620	0.440	0.180	0.400	0.580	.
80	5	21	0	7.4	180.0	22.0	42.0	38.00	14.00	0.06	0.06	0.040	.	0.910	0.410	0.370	0.040	0.500	0.540	0.3
80	5	21	20	7.3	180.0	21.0	42.0	39.00	15.00	0.06	0.04	0.030	.	0.990	0.590	0.540	0.050	0.400	0.450	0.2
80	5	21	60	7.0	200.0	25.0	44.0	40.00	15.00	0.42	0.69	0.020	.	0.930	0.530	0.210	0.320	0.400	0.720	2.0
80	6	2	0	7.3	200.0	22.0	42.0	40.00	15.00	0.08	0.04	0.030	0.000	0.600	0.300	0.280	0.020	0.300	0.320	0.0
80	6	2	20	7.2	190.0	21.0	44.0	39.00	15.00	0.10	0.03	0.030	0.000	0.580	0.280	0.260	0.020	0.300	0.320	0.0
80	6	2	50	6.7	200.0	23.0	42.0	39.00	13.00	0.23	0.45	0.020	0.010	0.830	0.430	0.190	0.240	0.400	0.640	3.2
80	6	2	60	6.9	210.0	24.0	44.0	41.00	14.00	0.47	0.70	0.020	0.010	0.750	0.450	0.120	0.330	0.300	0.630	2.6
80	6	19	0	7.5	220.0	18.0	41.0	36.00	14.00	0.13	0.05	0.010	0.010	0.770	0.470	0.440	0.030	0.300	0.330	0.0
80	6	19	20	7.5	200.0	20.0	41.0	34.00	13.00	0.08	0.05	0.070	0.010	0.800	0.500	0.470	0.030	0.300	0.330	0.0
80	6	19	50	6.9	220.0	20.0	41.0	40.00	13.00	0.34	0.46	0.040	0.010	0.950	0.550	0.340	0.210	0.400	0.610	1.6
80	6	19	55	7.5	220.0	28.0	41.0	37.00	13.00	0.65	0.62	0.040	0.010	1.020	0.620	0.300	0.320	0.400	0.720	2.4
80	7	2	0	7.3	190.0	20.0	41.0	38.00	3.00	0.03	0.02	0.090	0.040	0.760	0.560	0.500	0.060	0.200	0.260	0.8
80	7	2	20	7.4	190.0	20.0	38.0	28.00	13.00	0.04	0.02	0.020	0.040	0.670	0.470	0.390	0.080	0.200	0.280	0.8
80	7	2	50	7.1	210.0	22.0	41.0	35.00	10.00	0.24	0.46	0.040	0.010	1.200	0.700	0.570	0.130	0.500	0.630	4.6
80	7	2	55	7.5	200.0	25.0	41.0	39.00	12.00	0.60	0.60	0.040	0.020	0.670	0.270	-0.530	0.800	0.400	1.200	4.0
80	7	17	0	7.4	190.0	22.0	39.0	38.00	14.00	0.06	0.02	0.040	0.040	0.770	0.570	0.540	0.030	0.200	0.230	0.0
80	7	17	20	7.1	190.0	20.0	39.0	37.00	14.00	0.12	0.03	0.030	0.020	0.850	0.550	0.520	0.030	0.300	0.330	0.0
80	7	17	50	7.1	200.0	22.0	42.0	40.00	14.00	0.50	0.60	0.020	0.020	1.120	0.520	0.470	0.050	0.600	0.650	3.0
80	7	17	60	6.8	210.0	22.0	42.0	40.00	14.00	1.00	0.74	0.030	0.020	1.130	0.530	0.430	0.100	0.600	0.700	3.0
80	7	31	0	7.4	200.0	18.0	43.0	37.00	5.00	0.09	0.03	0.180	0.030	0.380	0.280	0.270	0.010	0.100	0.110	0.2
80	7	31	25	7.1	210.0	21.0	45.0	39.00	8.00	0.13	0.01	0.160	0.030	0.420	0.220	0.210	0.010	0.200	0.210	1.0
80	7	31	30	6.8	210.0	21.0	45.0	38.00	7.00	0.59	0.72	0.220	0.040	0.880	0.280	0.230	0.050	0.600	0.650	2.6
80	7	31	60	6.9	210.0	26.0	45.0	39.00	7.00	0.80	0.83	0.260	0.040	1.040	0.540	0.150	0.390	0.500	0.890	2.8
80	8	18	0	7.1	200.0	19.0	44.0	36.00	13.00	0.10	0.01	0.300	0.030	0.820	0.820	0.580	0.240	0.000	0.240	1.0
80	8	18	20	6.9	200.0	22.0	44.0	36.00	12.00	0.10	0.01	0.380	0.040	0.880	0.880	0.870	0.010	0.000	0.010	0.8
80	8	18	50	7.0	210.0	20.0	44.0	39.00	10.00	0.41	0.79	0.190	0.030	1.070	0.470	0.380	0.090	0.600	0.690	3.0
80	8	18	60	7.0	210.0	19.0	44.0	38.00	11.00	0.56	0.99	0.140	0.030	0.950	0.450	0.290	0.160	0.500	0.660	3.2
80	8	26	0	7.3	190.0	24.0	42.0	35.00	13.00	0.00	0.00	0.030	0.010	0.380	0.280	0.260	0.020	0.100	0.120	0.0
80	8	26	25	7.3	200.0	18.0	42.0	37.00	13.00	0.02	0.02	0.040	0.030	0.720	0.520	0.460	0.060	0.200	0.260	1.4
80	8	26	30	7.0	210.0	23.0	42.0	38.00	11.00	0.40	0.86	0.030	0.010	0.960	0.360	0.240	0.120	0.600	0.720	3.0
80	8	26	55	7.0	210.0	18.0	44.0	36.00	11.00	0.60	1.00	0.040	0.010	0.890	0.490	0.250	0.240	0.400	0.640	3.0
80	9	16	0	7.3	200.0	23.0	45.0	38.00	11.00	0.10	0.00	0.060	0.050	0.390	0.290	0.280	0.010	0.100	0.110	1.1

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LAKE QUINSIGAMOND AND FLINT POND CHEMICAL DATA FOR 1980

LAKE=QUINSIGAMOND   STATION=Q02 LAKE, 300 FT NO. RT.9   TYPE=LAKE

YEAR MONTH DAY DEPTH PHU  CND   ALK  HDN   CLD    SO4    IRN  MNG  TLP   TDP    TLN   TKN   ORN   NH3   NO3   INN  SIL

 80    9   16   30   6.9 210.0 23.0 45.0 38.00 12.00  0.10 0.21 0.040 0.040 0.700 0.400 0.280 0.120 0.300 0.420 3.9
 80    9   16   50   6.9 210.0 28.0 45.0 39.00  9.00  0.50 1.40 0.050 0.050 0.730 0.330 0.070 0.260 0.400 0.660 5.1
 80    9   18   60   7.0 230.0 51.0 54.0 40.00  5.00 13.00 2.60 0.370 0.140 1.500 1.400 0.200 1.200 0.100 1.300 8.2
 80    9   30    0   7.4 210.0 23.0 45.0 39.00 13.00  0.02 0.03 0.080 0.010 0.420 0.420 0.400 0.020 0.000 0.020 1.1
 80    9   30   30   7.2 210.0 23.0 45.0 39.00 12.00  0.00 0.01 0.080 0.010 0.410 0.410 0.380 0.030 0.000 0.030 1.5
 80    9   30   50   7.4 220.0 28.0 49.0 39.00 12.00  0.30 1.20 0.090 0.030 0.900 0.500 0.290 0.210 0.400 0.610 4.8
 80    9   30   60   7.4 220.0 29.0 46.0 39.00 11.00  0.41 1.30 0.100 0.020 0.840 0.540 0.220 0.320 0.300 0.620 4.4
 80   10   30    0   7.1 190.0 24.0 44.0 37.00 11.00  0.04 0.05 0.030   .   0.670 0.570 0.520 0.050 0.100 0.150 2.2
 80   10   30   50   7.4 210.0 30.0 47.0 38.00  9.00  0.15 0.95 0.030 0.030 1.090 0.890 0.560 0.330 0.200 0.530 4.8
 80   10   30   60   7.3 210.0 32.0 48.0 39.00 10.00  0.28 1.00 0.040 0.020 0.950 0.950 0.450 0.500 0.000 0.500 4.8
 80   11   13    0   6.9 200.0 25.0 44.0 37.00 11.00  0.12 0.10 0.070 0.030 1.600 1.500 1.300 0.200 0.100 0.300 2.9
 80   11   13   50   6.9 200.0 25.0 44.0 37.00 11.00  0.05 0.09 0.070 0.020 1.700 1.600 1.410 0.190 0.100 0.290 3.8
 80   11   13   65   7.1 210.0 27.0 44.0 38.00 12.00  0.09 0.11 0.060 0.040 1.200 1.100 0.900 0.200 0.100 0.300 2.5

LAKE=QUINSIGAMOND   STATION=Q03 LAKE, 300 FT SO. RT.8   TYPE=LAKE

YEAR MONTH DAY DEPTH PHU  CND   ALK  HDN   CLD    SO4    IRN  MNG  TLP   TDP    TLN   TKN    ORN   NH3   NO3   INN  SIL

 80    4    8    0   7.5 220.0 21.0 45.0 43.00   .    0.00 0.01 0.020   .   1.600 1.100  1.000 0.100 0.500 0.600  1.9
 80    4    8   20   7.5 220.0 21.0 47.0 44.00   .    0.04 0.06 0.030   .   1.140 0.740  0.690 0.050 0.400 0.450  1.7
 80    4    8   80   7.5 220.0 21.0 45.0 47.00   .    0.00 0.03 0.030   .   1.170 0.770  0.650 0.120 0.400 0.520  1.9
 80    4   24    0   7.4 210.0 20.0 43.0 42.00 16.00  0.11 0.03 0.030   .   1.350 0.950  0.910 0.040 0.400 0.440  2.3
 80    4   24   40   7.3 210.0 21.0 43.0 43.00 16.00  0.07 0.08 0.030   .   1.360 0.960  0.860 0.100 0.400 0.500  1.4
 80    4   24   75   7.2 220.0 23.0 45.0 41.00 14.00  0.18 0.62 0.030   .   1.500 1.100  0.840 0.260 0.400 0.660  2.0
 80    5    6    0   7.4 200.0 21.0 42.0 40.00 12.00  0.03 0.03 0.070   .   0.940 0.540  0.530 0.010 0.400 0.410   .
 80    5    6   20   7.4 200.0 20.0 42.0 38.00 13.00  0.02 0.03 0.040   .   0.810 0.410  0.390 0.020 0.400 0.420   .
 80    5    6   80   7.2 210.0 25.0 43.0 41.00 12.00  0.40 1.00 0.080   .   1.600 1.200  0.840 0.360 0.400 0.760   .
 80    5   21    0   7.6 190.0 21.0 42.0 39.00 16.00  0.05 0.03 0.030   .   0.630 0.230  0.130 0.100 0.400 0.500  0.2
 80    5   21   20   7.4 190.0 22.0 39.0 44.00 15.00  0.09 0.01 0.030   .   0.390 0.290  0.250 0.040 0.100 0.140  0.3
 80    5   21   80   7.0 220.0 33.0 48.0 45.00 15.00  1.40 2.90 0.070   .   1.060 0.860  0.120 0.740 0.200 0.940  4.5
 80    6    2    0   7.3 210.0 21.0 42.0 43.00 14.00  0.05 0.04 0.020 0.010 0.720 0.420  0.400 0.020 0.300 0.320  0.0
 80    6    2   20   7.1 200.0 21.0 42.0 42.00 14.00  0.02 0.06 0.030 0.010 0.800 0.400  0.300 0.100 0.400 0.500  0.0
 80    6    2   50   7.0 210.0 26.0 44.0 43.00 14.00  0.07 0.36 0.030 0.020 0.780 0.380  0.140 0.240 0.400 0.640  2.8
 80    6    2   80   6.9 230.0 35.0 47.0 44.00 15.00  2.00 2.70 0.060 0.040 1.060 0.910  0.170 0.740 0.150 0.890  5.4
 80    6   19    0   7.4 220.0 23.0 41.0 35.00 14.00  0.06 0.03 0.040 0.010 0.710 0.410  0.360 0.050 0.300 0.350  0.0
 80    6   19   20   7.4 220.0 20.0 41.0 39.00 13.00  0.08 0.06 0.040 0.010 1.000 0.700  0.670 0.030 0.300 0.330  0.0
 80    6   19   50   7.5 240.0 28.0 40.0 39.00 14.00  0.52 0.74 0.040 0.010 0.960 0.660  0.310 0.350 0.300 0.650  1.6
 80    6   19   80   7.5 250.0 37.0 40.0 41.00 13.00  3.00 2.60 0.110 0.050 1.200 1.200  0.100 1.100 0.000 1.100  3.4
 80    7    2    0   7.2 200.0 20.0 41.0 38.00 13.00  0.01 0.02 0.040 0.020 0.810 0.610  0.540 0.070 0.200 0.270 20.0
 80    7    2   20   7.5 200.0 20.0 41.0 37.00 14.00  0.05 0.03 0.020 0.020 0.740 0.440  0.340 0.100 0.300 0.400  2.2
 80    7    2   50   7.0 230.0 25.0 44.0 43.00 12.00  0.42 0.48 0.030 0.030 1.080 0.780  0.250 0.530 0.300 0.830  4.2
 80    7    2   70   7.2 240.0 37.0 45.0 43.00 13.00  3.90 1.30 0.060 0.040 1.600 1.500  0.300 1.200 0.100 1.300  6.8
 80    7   17    0   7.3 200.0 22.0 42.0 39.00 13.00  0.17 0.04 0.030 0.020 0.720 0.520  0.490 0.030 0.200 0.230  0.0
 80    7   17   20   7.1 190.0 20.0 42.0 38.00 13.00  0.05 0.03 0.030 0.010 1.140 0.540  0.020 0.520 0.600 1.120  0.0
 80    7   17   50   6.8 220.0 26.0 42.0 43.00 13.00  0.55 0.65 0.070 0.050 1.040 0.540  0.230 0.310 0.500 0.810  2.0
 80    7   17   80   6.9 240.0 43.0 46.0 43.00 26.00  8.00 3.00 0.230 0.150 2.000 1.900  0.100 1.800 0.100 1.900  2.2
 80    7   31    0   7.3 210.0 21.0 44.0 38.00  6.00  0.08 0.02 0.290 0.040 0.380 0.280  0.200 0.080 0.100 0.180  1.2
 80    7   31   25   7.2 215.0 22.0 45.0 41.00  7.00  1.20 0.14 0.390 0.030 0.470 0.470  0.440 0.030 0.000 0.030  1.0
 80    7   31   50   6.8 230.0 28.0 45.0 42.00  7.00  0.94 1.10 0.280 0.040 0.960 0.760  0.260 0.500 0.200 0.700  3.6
 80    7   31   75   7.0 260.0 53.0 51.0 43.00 26.00 10.00 3.00 0.790 0.390 3.000 2.900  0.000 2.900 0.100 3.000  6.2
 80    8   18    0   8.0 200.0 21.0 44.0 38.00 14.00  0.05 0.01 0.180 0.020 0.690 0.490  0.380 0.110 0.200 0.310  1.0
 80    8   18   20   7.5 200.0 20.0 42.0 38.00 12.00  0.09 0.02 0.290 0.030 0.660 0.660  0.660 0.000 0.000 0.000  1.0
 80    8   18   50   7.5 230.0 24.0 48.0 43.00 12.00  0.34 1.00 0.310 0.100 1.310 0.910  0.560 0.350 0.400 0.750  3.0
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LAKE QUINSIGAMOND AND FLINT POND CHEMICAL DATA FOR 1980

LAKE=QUINSIGAMOND STATION=Q03 LAKE, 300 FT SO. RT.9 TYPE=LAKE

YEAR	MONTH	DAY	DEPTH	PHU	CND	ALK	HDN	CLD	SO4	IRN	MNG	TLP	TDP	TLN	TKN	ORN	NH3	NO3	INN	SIL
80	8	18	80	7.6	250.0	46.0	50.0	44.00	6.00	10.00	3.40	0.910	0.350	3.000	3.000	0.100	2.900	0.000	2.900	7.0
80	8	26	0	7.2	200.0	20.0	42.0	37.00	13.00	0.02	0.02	0.020	0.010	0.460	0.360	0.350	0.010	0.100	0.110	0.2
80	8	26	20	7.1	200.0	21.0	42.0	42.00	12.00	0.00	0.02	0.020	0.010	0.490	0.390	0.380	0.010	0.100	0.110	0.6
80	8	26	50	7.0	230.0	27.0	48.0	42.00	11.00	1.60	1.50	0.080	0.050	1.130	0.930	0.110	0.820	0.200	1.020	4.4
80	8	26	75	7.4	260.0	32.0	50.0	43.00	5.00	12.00	3.40	0.700	0.550	4.000	3.900	0.200	3.700	0.100	3.800	9.8
80	9	16	0	7.5	200.0	25.0	42.0	38.00	13.00	0.10	0.03	0.050	0.040	0.300	0.300	0.290	0.010	0.000	0.010	4.4
80	9	16	30	7.6	220.0	28.0	51.0	42.00	13.00	0.06	0.48	0.050	0.030	0.590	0.390	0.250	0.140	0.200	0.340	1.6
80	9	16	50	7.2	230.0	37.0	51.0	43.00	11.00	1.90	1.90	0.120	0.070	0.890	0.790	0.000	0.790	0.100	0.890	1.9
80	9	16	75	7.1	260.0	62.0	54.0	44.00	3.00	14.00	4.00	0.680	0.210	2.500	2.500	0.000	2.500	0.000	2.500	1.8
80	9	30	0	7.4	320.0	24.0	45.0	39.00	12.00	0.00	0.02	0.110	0.030	0.530	0.530	0.510	0.020	0.000	0.020	1.8
80	9	30	30	7.2	210.0	27.0	45.0	39.00	12.00	0.00	0.14	0.120	0.050	0.580	0.580	0.490	0.090	0.000	0.090	2.8
80	9	30	50	7.0	235.0	32.0	49.0	43.00	11.00	0.45	1.30	0.090	0.050	0.690	0.690	0.080	0.610	0.000	0.610	4.7
80	9	30	80	7.4	265.0	62.0	51.0	43.00	4.00	13.00	3.20	0.680	0.280	2.500	2.500	0.100	2.400	0.000	2.400	11.0
80	10	30	0	7.2	200.0	22.0	47.0	39.00	11.00	0.03	0.05	0.030	0.030	0.740	0.640	0.460	0.180	0.100	0.280	2.2
80	10	30	50	6.6	230.0	33.0	50.0	43.00	9.00	0.34	1.80	0.060	0.030	0.990	0.990	0.260	0.730	0.000	0.730	5.2
80	10	30	80	6.7	250.0	64.0	56.0	43.00	6.00	14.00	3.70	0.610	0.410	3.200	3.200	-0.100	3.300	0.000	3.300	8.0
80	11	13	0	7.1	210.0	28.0	42.0	37.00	12.00	0.43	0.23	0.100	0.030	1.300	1.200	0.810	0.390	0.100	0.490	3.8
80	11	13	50	7.0	210.0	26.0	45.0	39.00	11.00	0.39	0.18	0.040	0.040	2.200	2.100	1.680	0.420	0.100	0.520	3.6
80	11	13	80	6.9	210.0	28.0	47.0	38.00	12.00	0.32	0.27	0.220	0.030	1.600	1.500	1.110	0.390	0.100	0.490	3.6

LAKE=QUINSIGAMOND STATION=Q04 LAKE, 1000 FT NO.BRIDLE PATH STM.DR TYPE=LAKE

YEAR	MONTH	DAY	DEPTH	PHU	CND	ALK	HDN	CLD	SO4	IRN	MNG	TLP	TDP	TLN	TKN	ORN	NH3	NO3	INN	SIL
80	4	8	0	7.5	220.0	23.0	48.0	49.00	.	0.00	0.00	0.020	.	1.290	0.890	0.790	0.100	0.400	0.500	1.3
80	4	8	25	7.2	240.0	21.0	48.0	44.00	.	0.00	0.06	0.020	.	1.170	0.770	0.640	0.130	0.400	0.530	1.8
80	4	8	50	7.1	220.0	21.0	48.0	37.00	.	0.00	0.02	0.020	.	1.400	1.100	1.000	0.100	0.300	0.400	1.6
80	4	24	0	7.6	220.0	21.0	45.0	42.00	15.00	0.09	0.05	0.030	.	1.240	0.840	0.820	0.020	0.400	0.420	2.0
80	4	24	30	7.3	220.0	21.0	45.0	46.00	15.00	0.08	0.05	0.030	.	1.310	0.910	0.840	0.070	0.400	0.470	1.2
80	4	24	45	7.1	220.0	24.0	45.0	45.00	15.00	0.19	0.43	0.030	.	1.290	0.990	0.720	0.270	0.300	0.570	1.9
80	5	6	0	7.5	210.0	20.0	42.0	42.00	13.00	0.00	0.15	0.060	.	0.870	0.470	0.450	0.020	0.400	0.420	.
80	5	6	30	7.3	210.0	21.0	42.0	46.00	14.00	0.06	0.13	0.050	.	0.940	0.540	0.450	0.090	0.400	0.490	.
80	5	6	50	7.1	230.0	26.0	45.0	44.00	12.00	0.40	1.00	0.060	.	1.190	0.890	0.420	0.470	0.300	0.770	.
80	5	21	0	7.7	200.0	22.0	44.0	45.00	14.00	0.06	0.00	0.040	.	0.630	0.330	0.280	0.050	0.300	0.350	0.0
80	5	21	20	7.6	200.0	22.0	44.0	43.00	13.00	0.05	0.01	0.040	.	0.660	0.360	0.320	0.040	0.300	0.340	0.5
80	5	21	50	7.0	230.0	36.0	44.0	46.00	11.00	0.71	2.00	0.080	.	1.140	0.840	0.030	0.810	0.300	1.110	3.0
80	6	2	0	7.4	210.0	23.0	44.0	43.00	14.00	0.04	0.02	0.010	0.010	0.370	0.370	0.340	0.030	0.000	0.030	0.0
80	6	2	20	7.3	200.0	22.0	42.0	44.00	15.00	0.03	0.04	0.020	0.010	0.410	0.410	0.390	0.020	0.000	0.020	0.0
80	6	2	50	6.8	240.0	42.0	44.0	43.00	8.00	5.00	4.50	0.230	0.230	9.500	1.500	0.400	1.100	8.000	9.100	8.0
80	6	19	0	7.5	230.0	23.0	40.0	38.00	13.00	0.30	0.24	0.080	0.010	0.580	0.380	0.380	0.000	0.200	0.200	0.0
80	6	19	20	7.4	230.0	26.0	41.0	38.00	13.00	0.09	0.06	0.060	0.010	0.680	0.480	0.480	0.000	0.200	0.200	0.0
80	6	19	45	7.5	270.0	42.0	40.0	41.00	15.00	4.50	3.50	0.320	0.280	1.900	1.900	0.100	1.800	0.000	1.800	6.0
80	7	2	0	7.1	210.0	20.0	39.0	39.00	15.00	0.01	0.00	0.020	0.020	0.810	0.510	0.430	0.080	0.300	0.380	1.8
80	7	2	20	7.5	210.0	20.0	42.0	39.00	14.00	0.05	0.02	0.030	0.020	0.650	0.450	0.370	0.080	0.200	0.280	1.6
80	7	2	45	7.6	240.0	37.0	42.0	44.00	9.00	3.80	2.50	0.170	0.160	1.800	1.700	0.200	1.500	0.100	1.600	5.6
80	7	17	0	7.7	200.0	23.0	39.0	39.00	15.00	0.09	0.03	0.070	0.050	0.410	0.310	0.310	0.000	0.100	0.100	2.2
80	7	17	20	7.4	200.0	20.0	39.0	36.00	15.00	0.09	0.03	0.050	0.030	0.450	0.350	0.340	0.010	0.100	0.110	0.0
80	7	17	50	6.8	250.0	50.0	46.0	45.00	18.00	6.30	3.00	0.420	0.360	2.700	2.200	0.000	2.200	0.500	2.700	5.8
80	7	31	0	7.8	210.0	21.0	42.0	40.00	6.00	0.21	0.05	0.340	0.050	0.500	0.500	0.500	0.000	0.000	0.000	1.0
80	7	31	25	6.9	215.0	23.0	44.0	40.00	7.00	0.11	0.11	0.240	0.040	0.330	0.330	0.290	0.040	0.000	0.040	1.6
80	7	31	45	6.8	260.0	48.0	44.0	41.00	12.00	5.60	2.90	0.760	0.320	2.900	2.900	0.300	2.600	0.000	2.600	6.0
80	8	18	0	7.3	200.0	21.0	44.0	37.00	13.00	0.12	0.05	0.230	0.040	0.650	0.650	0.640	0.010	0.000	0.010	1.4
80	8	18	20	7.3	200.0	19.0	44.0	38.00	13.00	0.00	0.08	0.300	0.020	0.780	0.780	0.730	0.050	0.000	0.050	1.4

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. LAKE QUINSIGAMOND AND FLINT POND CHEMICAL DATA FOR 1980

LAKE=QUINSIGAMOND   STATION=Q04 LAKE, 1000 FT NO.BRIDLE PATH STM.DR   TYPE=LAKE

YEAR MONTH DAY DEPTH PHU  CND   ALK   HDN   CLD    SO4  IRN  MNG   TLP   TDP   TLN   TKN   ORN   NH3   NO3   INN  SIL

 80    8   18   50   7.4 250.0 43.0 47.0 45.00  5.00 0.12 3.10 0.410 0.200 2.600 2.600 0.200 2.400 0.000 2.400 6.0
 80    8   26    0   7.2 200.0 22.0 44.0 37.00 13.00 0.00 0.00 0.020 0.020 0.330 0.330 0.300 0.030 0.000 0.030 0.4
 80    8   26   20   7.0 200.0 21.0 42.0 38.00 12.00 0.02 0.05 0.010 0.010 0.490 0.390 0.370 0.020 0.100 0.120 0.4
 80    8   26   45   7.1 250.0 47.0 48.0 44.00  4.00 6.00 3.20 0.520 0.450 3.400 3.300 0.300 3.000 0.100 3.100 8.0
 80    9   16    0   7.6 200.0 25.0 45.0 40.00 11.00 0.04 0.03 0.070 0.040 0.330 0.330 0.310 0.020 0.000 0.020 1.2
 80    9   16   30   7.2 240.0 40.0 51.0 42.00  7.00 1.10 2.80 0.060 0.040 0.730 0.730 0.000 0.730 0.000 0.730 1.9
 80    9   16   50   7.2 260.0 59.0 54.0 45.00  2.00 7.10 3.70 0.530 0.300 2.500 2.400 0.000 2.400 0.100 2.500 3.5
 80    9   30    0   7.4 215.0 23.0 43.0 41.00 13.00 0.03 0.12 0.100 0.070 0.440 0.440 0.410 0.030 0.000 0.030 1.9
 80    9   30   30   7.0 230.0 36.0 45.0 41.00  9.00 1.00 2.00 0.090 0.060 0.800 0.800 0.120 0.680 0.000 0.680 5.9
 80    9   30   50   7.1 265.0 57.0 48.0 43.00  2.00 6.50 2.10 0.620 0.210 2.500 2.500 0.100 2.400 0.000 2.400 9.5
 80   10   30    0   6.9 210.0 28.0 47.0 39.00 11.00 0.08 0.03 0.050 0.050 1.130 0.830 0.630 0.200 0.300 0.500 3.0
 80   10   30   45   6.8 210.0 32.0 47.0 40.00 10.00 0.23 0.43 0.090 0.050 1.200 1.100 0.590 0.510 0.100 0.610 3.7
 80   10   30   50   6.7 240.0 50.0 54.0 44.00  8.00 6.10 2.90 0.400 0.130 3.000 2.900 0.400 2.500 0.100 2.600 7.7
 80   11   13    0   7.1 210.0 25.0 45.0 39.00 11.00 0.05 0.05 0.060 0.020 1.600 1.500 1.310 0.190 0.100 0.290 3.4
 80   11   13   45   6.9 210.0 24.0 45.0 38.00 11.00 0.03 0.03 0.170 0.030 1.400 1.100 0.900 0.200 0.300 0.500 3.2
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LAKE=QUINSIGAMOND   STATION=Q05 LAKE @ I-290 BRIDGE   TYPE=LAKE

YEAR MONTH DAY DEPTH PHU  CND   ALK   HDN   CLD    SO4  IRN  MNG   TLP    TDP   TLN   TKN    ORN   NH3   NO3   INN  SIL

 80    4    8    0   7.1 210.0 20.0 44.0 38.00   .   0.00 0.03 0.050  .    1.350 0.950  0.870 0.080 0.400 0.480 2.1
 80    4   24    0   7.5 200.0 20.0 42.0 37.00 15.00 0.08 0.02 0.060 . .  1.340 0.940  0.910 0.030 0.400 0.430 1.7
 80    5    6    0   7.5 180.0 19.0 42.0 34.00 13.00 0.10 0.04 0.040  .    0.870 0.470  0.450 0.020 0.400 0.420  .
 80    5   21    0   7.0 180.0 25.0 42.0 38.00 12.00 0.02 0.00 0.040  .    0.700 0.400  0.370 0.030 0.300 0.330 0.6
 80    6    2    0   7.2 190.0 22.0 42.0 35.00 12.00 0.10 0.04 0.020 0.010 0.610 0.310 -0.390 0.700 0.300 1.000 0.3
 80    6   19    0   7.5 210.0 20.0 41.0 34.00 13.00 0.22 0.05 0.060 0.010 0.740 0.540  0.530 0.010 0.200 0.210 0.0
 80    7    2    0   7.5 190.0 19.0 39.0 36.00 12.00 0.05 0.01 0.040 0.040 0.740 0.540  0.450 0.090 0.200 0.290 2.2
 80    7   17    0   7.3 190.0 20.0 39.0 37.00 13.00 0.12 0.03   .     .   0.480 0.280  0.260 0.020 0.200 0.220 0.0
 80    7   31    0   7.0 200.0 19.0 42.0 35.00  5.00 1.50 0.18 0.370 0.040 0.600 0.500  0.490 0.010 0.100 0.110 1.0
 80    8   18    0   7.3 200.0 16.0 21.3 37.00 11.00 0.05 0.10 0.020 0.030 0.470 0.470  0.460 0.010 0.000 0.010 2.2
 80    8   26    0   7.1 200.0 23.0 42.0 36.00 12.00 0.00 0.00 0.030 0.030 0.360 0.360  0.350 0.010 0.000 0.010 0.0
 80    9   16    0   7.5 200.0 22.0 45.0 38.00 11.00 0.03 0.01 0.060 0.040 0.330 0.330  0.320 0.010 0.000 0.010 0.1
 80    9   30    0   7.4 210.0 23.0 48.0 39.00 13.00 0.03 0.06 0.120 0.080 0.490 0.490  0.460 0.030 0.000 0.030 1.7
 80   10   30    0   6.9 190.0 27.0 44.0 37.00 12.00 0.04 0.01 0.050 0.030 0.850 0.650  0.580 0.070 0.200 0.270 2.2
 80   11   13    0   7.0 210.0 27.0 39.0 36.00 12.00 0.20 0.22 0.050 0.030 1.900 1.800  1.570 0.230 0.100 0.330 3.6
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LAKE=QUINSIGAMOND   STATION=Q06 LAKE @ RT.9 BRIDGE   TYPE=LAKE

YEAR MONTH DAY DEPTH PHU  CND   ALK   HDN   CLD    SO4  IRN  MNG   TLP   TDP   TLN   TKN   ORN   NH3   NO3   INN  SIL

 80    4    8    0   7.1 210.0 20.0 44.0 38.00   .   0.00 0.03 0.050  .    1.350 0.950 0.870 0.080 0.400 0.480 2.1
 80    4   24    0   7.5 190.0 20.0 42.0 37.00 15.00 0.06 0.02 0.030  .    1.270 0.870 0.840 0.030 0.400 0.430 1.7
 80    5    6    0   7.4 180.0 18.0 39.0 35.00 13.00 0.10 0.03 0.050  .    0.900 0.500 0.480 0.020 0.400 0.420  .
 80    5   21    0   7.3 180.0 21.0 42.0 36.00 14.00 0.06 0.02 0.020  .    0.700 0.400 0.350 0.050 0.300 0.350 0.5
 80    6    2    0   7.3 200.0 21.0 42.0 38.00 14.00 0.08 0.03 0.010 0.010 0.220 0.220 0.210 0.010 0.000 0.010 0.0
 80    6   19    0   7.4 210.0 19.0 41.0 37.00 13.00 0.28 0.04 0.050 0.010 0.690 0.490 0.470 0.020 0.200 0.220 0.0
 80    7    2    0   7.5 200.0 20.0 39.0 37.00 13.00 0.04 0.02 0.020 0.020 0.660 0.460 0.390 0.070 0.200 0.270 2.0
 80    7   17    0   7.3 200.0 21.0 42.0 38.00 13.00 0.06 0.03 0.060 0.030 0.320 0.220 0.210 0.010 0.100 0.110 0.2
 80    7   31    0   7.2 200.0 21.0 61.0 37.00  6.00 0.53 0.09 0.410 0.030 0.340 0.340 0.340 0.000 0.000 0.000 0.2
 80    8   18    0   7.6 200.0 20.0 44.0 37.00 11.00 0.06 0.05 0.010 0.010 0.380 0.380 0.370 0.010 0.000 0.010 1.2
 80    8   26    0   6.6 190.0 19.0 42.0 36.00 13.00 0.02 0.00 0.020 0.020 0.430 0.330 0.320 0.010 [illegible] 0.110 0.0
 80    9   16    0   7.2 200.0 24.0 45.0 39.00 12.00 0.00 0.01 0.050 0.020 0.280 0.280 0.270 0.010 0.000 0.010 0.4
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LAKE QUINSIGAMOND AND FLINT POND CHEMICAL DATA FOR 1980

LAKE=QUINSIGAMOND   STATION=Q06 LAKE @ RT.9 BRIDGE   TYPE=LAKE

YEAR MONTH DAY DEPTH PHU  CND   ALK   HDN   CLD   SO4   IRN  MNG   TLP   TDP   TLN   TKN   ORN   NH3   NO3   INN  SIL

 80    9   30    0   7.3 210.0 23.0 48.0 39.00 13.00 0.00 0.05 0.110 0.050 0.570 0.570 0.550 0.020 0.000 0.020 1.8
 80   10   30    0   6.9 190.0 32.0 44.0 40.00 13.00 0.06 0.04 0.040 0.020 0.940 0.840 0.760 0.080 0.100 0.180 2.3
 80   11   13    0   7.1 210.0 29.0 47.0 40.00 11.00 0.07 0.21 0.100 0.030 1.800 1.700 1.310 0.390 0.100 0.490 3.9

LAKE=QUINSIGAMOND   STATION=Q08 FITZGERALD BROOK   TYPE=TRIBUTARY

YEAR MONTH DAY DEPTH PHU  CND   ALK   HDN   CLD   SO4   IRN  MNG   TLP   TDP   TLN   TKN   ORN   NH3   NO3   INN  SIL

 80    3    3    0   6.9 250.0 19.0 59.0 49.00 26.00 0.21 0.04 0.080   .   1.460 0.560 0.520 0.040 0.900 0.940   .
 80    4    8    0   7.6 290.0 25.0 79.0 51.00   .   0.00 0.05 0.030   .   1.790 0.490 0.470 0.020 1.300 1.320 10.0
 80    4   24    0   7.9 290.0 25.0 71.0 51.00 29.00 0.07 0.02 0.030   .   2.250 0.950 0.920 0.030 1.300 1.330 11.0
 80    5    6    0   7.9 290.0 26.0 70.0 49.00 29.00 0.02 0.02 0.040   .   1.680 0.480 0.470 0.010 1.200 1.210   .
 80    5   21    0   7.5 270.0 28.0 67.0 52.00 27.00 0.10 0.04 0.090   .   1.810 0.510 0.510 0.000 1.300 1.300 10.0
 80    6    2    0   7.2 280.0 29.0 64.0 44.00 27.00 0.17 0.08 0.160 0.060 2.000 0.800 0.510 0.290 1.200 1.490 12.0
 80    6   19    0   7.5 360.0 24.0 74.0 57.00 29.00 0.09 0.00 0.090 0.040 1.890 0.390 0.360 0.030 1.500 1.530 12.0
 80    7    2    0   7.7 280.0 28.0 64.0 43.00 29.00 0.07 0.01 0.050 0.040 2.020 0.820 0.720 0.100 1.200 1.300 14.0
 80    7   17    0   7.3 350.0 30.0 86.0 60.00 31.00 0.05 0.01 0.080 0.050 2.030 0.430 0.030 0.400 1.600 2.000 20.0
 80    7   31    0   7.3 310.0 26.0 64.0 54.00 16.00 0.05 0.02 0.180 0.060 1.430 0.330 0.330 0.000 1.100 1.100 11.0
 80    8   18    0   7.6 340.0 27.0 80.0 59.00 25.00 0.18 0.02 0.090 0.090 1.820 0.320 0.290 0.030 1.500 1.530 14.0
 80    8   26    0   7.0 340.0 26.0 84.0 59.00 29.00 0.02 0.00 0.090 0.090 1.780 0.180 0.160 0.020 1.600 1.620 15.0
 80   10   30    0   7.1 270.0 28.0 74.0 44.00 32.00 0.07 0.22 0.060 0.040 1.660 0.560 0.550 0.010 1.100 1.110 14.0
 80   11   13    0   7.4 300.0 27.0 74.0 48.00 87.00 0.00 0.01 0.080 0.070 2.280 0.980 0.960 0.020 1.300 1.320 13.0

LAKE=QUINSIGAMOND   STATION=Q09 COALMINE BROOK   TYPE=TRIBUTARY

YEAR MONTH DAY DEPTH PHU  CND   ALK   HDN     CLD   SO4   IRN  MNG   TLP   TDP   TLN   TKN   ORN   NH3   NO3   INN  SIL

 80    3    3    0   7.8 400.0 45.0 100.0  78.00 26.00 0.04 0.02 0.070   .   1.400 0.500 0.470 0.030 0.900 0.930   .
 80    4    8    0   7.6 340.0 24.0  86.0  64.00   .   0.00 0.08 0.040   .   1.330 0.430 0.390 0.040 0.900 0.940  8.7
 80    4   24    0   8.2 320.0 34.0  79.0  59.00 27.00 0.06 0.03 0.040   .   1.550 0.950 0.930 0.020 0.600 0.620  7.8
 80    5    6    0   8.1 330.0 35.0  83.0  62.00 27.00 0.05 0.02 0.070   .   1.010 0.410 0.400 0.010 0.600 0.610   .
 80    5   21    0   7.4 290.0 36.0  70.0  55.00 25.00 0.12 0.02 0.170   .   1.610 0.810 0.750 0.060 0.800 0.860  7.5
 80    6    2    0   7.3 330.0 40.0  86.0  51.00 27.00 0.38 0.08 0.100 0.050 1.890 0.790 0.540 0.250 1.100 1.350  9.6
 80    6   19    0   7.7 340.0 22.0  76.0  52.00 26.00 0.24 0.06 0.100 0.040 1.030 0.430 0.430 0.000 0.600 0.600  8.6
 80    7    2    0   7.7 340.0 45.0  86.0  59.00 29.00 0.06 0.01 0.040 0.040 1.040 0.440 0.400 0.040 0.600 0.640 10.0
 80    7   17    0   7.5 300.0 40.0  71.0  52.00 23.00 0.04 0.02 0.080 0.050 1.060 0.360 0.310 0.050 0.700 0.750 13.0
 80    7   31    0   7.5 310.0 40.0  79.0  53.00 10.00 0.15 0.02 0.100 0.090 0.880 0.580 0.570 0.010 0.300 0.310  7.6
 80    8   18    0   7.5 310.0 29.0  76.0 109.00 21.00 0.00 0.01 0.080 0.070 1.400 0.300 0.200 0.100 1.100 1.200  9.6
 80    8   26    0   7.1 290.0 36.0  74.0  52.00 22.00 0.02 0.01 0.100 0.100 1.400 0.300 0.220 0.080 1.100 1.180 10.0
 80   10   30    0   7.3 340.0 48.0  95.0  58.00 29.00 0.05 0.01 0.050 0.050 1.010 0.310 0.300 0.010 0.700 0.710 10.0
 80   11   13    0   7.5 360.0 42.0 110.0  61.00 27.00 0.03 0.00 0.090 0.090 1.340 0.740 0.730 0.010 0.600 0.610 14.0
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LAKE QUINSIGAMOND AND FLINT POND CHEMICAL DATA FOR 1980

LAKE=QUINSIGAMOND   STATION=Q10 POOR FÅRM BROOK   TYPE=TRIBUTARY

YEAR MONTH DAY DEPTH PHU  CND   ALK  HDN   CLD   SO4   IRN  MNG  TLP   TDP   TLN   TKN   ORN   NH3   NO3   INN  SIL

 80    3    3    0   7.4 320.0 40.0 85.0 62.00 31.00 0.08 0.18 0.060  .    1.550 0.550 0.470 0.080 1.000 1.080  .
 80    4    8    0   7.6 240.0 29.0 63.0 39.00   .   0.10 0.08 0.030  .    1.380 0.480 0.440 0.040 0.900 0.940 9.0
 80    4   24    0   8.2 240.0 30.0 61.0 41.00 18.00 0.56 0.10 0.040  .    1.540 0.740 0.700 0.040 0.800 0.840 6.7
 80    5    6    0   7.8 240.0 33.0 60.0 40.00 16.00 0.47 0.13 0.040  .    1.040 0.440 0.420 0.020 0.600 0.620  .
 80    5   21    0   7.7 230.0 39.0 58.0 42.00 18.00 0.26 0.02 0.050  .    0.790 0.390 0.370 0.020 0.400 0.420 4.9
 80    6    2    0   7.5 250.0 45.0 67.0 42.00 16.00 0.67 0.08 0.050 0.020 0.820 0.470 0.420 0.050 0.350 0.400 0.3
 80    6   19    0   7.6 270.0 29.0 63.0 42.00 18.00 1.40 0.18 0.080 0.030 0.910 0.610 0.540 0.070 0.300 0.370 5.8
 80    7    2    0   7.5 220.0 32.0 54.0 33.00 16.00 0.63 0.03 0.050 0.030 1.250 0.750 0.520 0.230 0.500 0.730 9.4
 80    7   17    0   7.0 270.0 58.0 73.0 20.00 18.00 1.10 0.73 0.110 0.090 1.200 1.200 1.160 0.040 0.000 0.040 8.6
 80    7   31    0   6.9 180.0 26.0 43.0 27.00  9.00 1.30 0.16 0.090 0.040 1.140 0.840 0.720 0.120 0.300 0.420 5.4
 80    8   26    0   7.4 260.0 50.0 84.0 30.00 11.00 1.00 0.80 0.100 0.030 1.030 0.930 0.780 0.150 0.100 0.250 6.8
 80   10   30    0   6.9 240.0 33.0 66.0 39.00 22.00 0.60 0.10 0.050 0.040 1.010 0.810 0.570 0.040 0.400 0.440 9.6
 80   11   13    0   7.3 240.0 33.0 63.0 38.00 18.00 0.76 0.07 0.070 0.050 1.310 0.910 0.850 0.060 0.400 0.460 8.5

LAKE=QUINSIGAMOND   STATION=Q11 NEWTON POND OUTLET   TYPE=TRIBUTARY

YEAR MONTH DAY DEPTH PHU  CND   ALK  HDN   CLD   SO4   IRN  MNG  TLP   TDP   TLN   TKN   ORN   NH3   NO3   INN  SIL

 80    3    3    0   7.3 140.0 18.0 38.0 22.00 14.00 0.20 0.02 0.040  .    0.630 0.430 0.390 0.040 0.200 0.240  .
 80    4    8    0   7.3 100.0 12.0 27.0 14.00   .   0.00 0.03 0.030  .    0.710 0.410 0.380 0.030 0.300 0.330 1.1
 80    4   24    0   7.4  96.0 14.0 25.0 11.00 11.00 0.13 0.00 0.030  .    1.040 0.840 0.790 0.050 0.200 0.250 1.2
 80    5    6    0   7.4 100.0 14.0 26.0 13.00  9.00 0.13 0.03 0.010  .    0.810 0.610 0.580 0.030 0.200 0.230  .
 80    5   21    0   7.4 100.0 16.0 27.0 17.00 10.00 0.07 0.00 0.020  .    0.490 0.290 0.250 0.040 0.200 0.240 0.0
 80    6    2    0   7.0 110.0 19.0 27.0 52.00  8.00 0.13 0.04 0.030 0.040 0.730 0.620 0.580 0.040 0.110 0.150 0.0
 80    6   19    0   7.1 130.0 16.0 28.0 17.00  9.00 0.32 0.05 0.040 0.010 0.680 0.680 0.680 0.000 0.000 0.000 0.0
 80    7    2    0   7.3 125.0 20.0 29.0 18.00  7.00 0.14 0.03 0.020 0.020 0.710 0.610 0.560 0.050 0.100 0.150 1.0
 80    7   17    0   7.0 130.0 24.0 30.0 22.00  9.00 0.50 0.25 0.030 0.010 0.550 0.550 0.550 0.000 0.000 0.000 0.0
 80    7   31    0   6.9 130.0 21.0 32.0 23.00  5.00 0.24 0.04 0.040 0.030 0.740 0.740 0.740 0.000 0.000 0.000 1.2
 80    8   18    0   7.1 130.0 18.0 32.0 22.00  5.00 0.38 0.00 0.030 0.020 0.380 0.380 0.170 0.210 0.000 0.210 2.0
 80    9   16    0   7.0 140.0 21.0 33.0 22.00  6.00 0.24 0.03 0.060 0.030 0.360 0.260 0.240 0.020 0.100 0.120 0.1
 80    9   30    0   7.2 140.0 20.0 30.0 23.00  7.00 0.10 0.00 0.070 0.060 0.480 0.480 0.470 0.010 0.000 0.010 0.4
 80   10   30    0   7.1 125.0 20.0 30.0 22.00  7.00 0.08 0.00 0.020 0.020 0.510 0.410 0.410 0.000 0.100 0.100 0.2
 80   11   13    0   7.2 170.0 20.0 38.0 26.00 10.00 0.05 0.03 0.110 0.040 1.000 1.000 0.990 0.010 0.000 0.010 0.7

LAKE=QUINSIGAMOND   STATION=Q12 LAKE @ LINCOLN ST.   TYPE=LAKE

YEAR MONTH DAY DEPTH PHU  CND   ALK  HDN   CLD   SO4   IRN  MNG  TLP   TDP   TLN   TKN   ORN   NH3   NO3   INN  SIL

 80    4    8    0   7.3 150.0 19.0 42.0 25.00   .   0.06 0.04 0.030  .    0.950 0.450 0.390 0.060 0.500 0.560 2.7
 80    4   24    0   7.5 150.0 21.0 39.0 23.00 14.00 0.27 0.06 0.020  .    1.500 1.100 1.050 0.050 0.400 0.450 2.3
 80    5    6    0   7.5 140.0 20.0 32.0 22.00 11.00 0.32 0.10 0.030  .    0.680 0.480 0.460 0.020 0.200 0.220  .
 80    5   21    0   7.3 130.0 15.0 32.0 23.00 15.00 0.08 0.02 0.080  .    0.700 0.600 0.530 0.070 0.100 0.170 0.4
 80    6    2    0   7.1 150.0 33.0 39.0 24.00 10.00 0.26 0.08 0.100 0.070 0.670 0.670 0.580 0.090 0.000 0.090 0.9
 80    6   19    0   7.4 155.0 21.0 35.0 22.00  9.00 0.56 0.16 0.040 0.010 0.740 0.740 0.670 0.070 0.000 0.070 0.0
 80    7    2    0   7.7 125.0 28.0 30.0 19.00  9.00 0.12 0.01 0.040 0.030 0.600 0.500 0.370 0.130 0.100 0.230 2.4
 80    7   17    0   6.8 150.0 24.0 33.0 48.00 10.00 0.45 0.08 0.070 0.040 0.740 0.740 0.730 0.010 0.000 0.010 0.0
 80    7   31    0   6.7 120.0 16.0 27.0 19.00  6.00 0.46 0.05 0.060 0.050 0.750 0.750 0.710 0.040 0.000 0.040 1.8
 80    8   18    0   7.2 130.0 22.0 32.0 23.00  6.00 0.31 0.02 0.040 0.010 0.760 0.760 0.740 0.020 0.000 0.020 1.0
 80    8   26    0   7.4 200.0 21.0 44.0 36.00 13.00 0.10 0.02 0.010 0.010 0.710 0.510 0.450 0.060 0.200 0.260 0.0
 80    9   16    0   7.0 200.0 22.0 42.0 38.00 12.00 0.06 0.00 0.050 0.030 0.340 0.340 0.330 0.010 0.000 0.010 1.0
 80    9   30    0   7.3 210.0 23.0 44.0 38.00 13.00 0.00 0.02 0.080 0.040 1.200 1.200 1.160 0.040 0.000 0.040 1.6
 80   10   30    0   6.8 125.0 20.0 32.0 21.00  9.00 0.14 0.00 0.040 0.040 0.750 0.750 0.740 0.010 0.000 0.010 1.3
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LAKE QUINSIGAMOND AND FLINT POND CHEMICAL DATA FOR 1980

LAKE=QUINSIGAMOND    STATION=Q12 LAKE @ LINCOLN ST.    TYPE=LAKE

YEAR MONTH DAY DEPTH PHU  CND   ALK   HDN   CLD   SO4   IRN  MNG   TLP   TDP   TLN   TKN   ORN   NH3   NO3   INN  SIL

 80   11   13    0   7.0 130.0 19.0  29.0 19.00  7.00 0.03 0.02 0.150 0.030 0.920 0.820 0.810 0.010 0.100 0.110 0.3

LAKE=QUINSIGAMOND    STATION=Q13 BILLINGS BROCK    TYPE=TRIBUTARY

YEAR MONTH DAY DEPTH PHU  CND   ALK   HDN   CLD   SO4   IRN  MNG   TLP   TDP   TLN   TKN   ORN   NH3   NO3   INN  SIL

 80    3     3   0   6.7 180.0 21.0  43.0 30.00 23.00 1.07 0.08 0.040   .   1.520 0.520 0.470 0.050 1.000 1.050  .
 80    4     8   0   6.8 190.0 19.0  42.0 33.00   .   0.16 0.10 0.040   .   1.600 1.000 0.930 0.070 0.600 0.670 6.1
 80    4    24   0   7.4 160.0 20.0  36.0 40.00 15.00 0.88 0.04 0.060   .   1.600 1.200 1.060 0.140 0.400 0.540 4.3
 80    5     6   0   7.2 180.0 21.0  42.0 32.00 12.00 1.10 0.13 0.020   .   1.060 0.660 0.540 0.120 0.400 0.520  .
 80    5    21   0   6.8 200.0 20.0  47.0 43.00 16.00 1.20 0.07 0.040   .   0.860 0.360 0.280 0.080 0.500 0.580 4.9
 80    6     2   0   7.2 260.0 34.0  54.0 53.00 17.00 0.83 0.13 0.060 0.020 1.000 0.400 0.330 0.070 0.600 0.670 7.0
 80    6    19   0   7.0 300.0 14.0  59.0 61.00 20.00 0.13 0.12 0.040 0.020 1.050 0.550 0.180 0.370 0.500 0.870 5.4
 80    7     2   0   7.0 250.0 16.0  53.0 48.00 15.00 0.32 0.03 0.040 0.020 1.320 0.820 0.610 0.210 0.500 0.710 6.6
 80    7    17   0   6.8 250.0 18.0  49.0 55.00 24.00 1.60 0.20 0.060 0.020 1.270 0.670 0.540 0.130 0.600 0.730 1.2
 80    7    31   0   6.7 260.0 15.0  68.0 55.00  8.00 0.89 0.09 0.050 0.030 1.130 0.730 0.670 0.060 0.400 0.460 6.8
 80    8    18   0   7.1 220.0 24.0  49.0 41.00 18.00 0.53 0.01 0.180 0.020 1.160 0.460 0.430 0.030 0.700 0.730 7.4
 80    8    26   0   7.0 230.0 18.0  49.0 37.00 16.00 0.55 0.09 0.020 0.020 0.930 0.330 0.250 0.080 0.600 0.680 7.0
 80    9    16   0   6.8 220.0 21.0  53.0 40.00 17.00 0.65 0.08 0.050 0.030 0.650 0.250 0.190 0.060 0.400 0.460 3.5
 80    9    30   0   6.7 220.0 21.0  45.0 38.00 18.00 0.43 0.11 0.070 0.040 2.000 1.100 1.030 0.070 0.900 0.970 9.3
 80   10    30   0   6.5 230.0 17.0 113.0 42.00 21.00 0.18 0.11 0.070 0.010 1.420 0.620 0.580 0.040 0.800 0.840 8.5
 80   11    13   0   6.8 230.0 18.0  56.0 40.00 19.00 0.22 0.02 0.060 0.040 2.500 1.700 1.680 0.020 0.800 0.820 8.2

LAKE=QUINSIGAMOND    STATION=Q15 O HARA BROOK    TYPE=TRIBUTARY

YEAR MONTH DAY DEPTH PHU  CND   ALK   HDN   CLD   SO4   IRN  MNG   TLP   TDP   TLN   TKN   ORN   NH3   NO3   INN   SIL

 80    4     8   0   7.2 230.0 21.0  48.0 47.00   .   0.00 0.05 0.030   .   1.170 0.770 0.700 0.070 0.400 0.470  1.9
 80    5     6   0   7.1 290.0 36.0  62.0 55.00 25.00 0.10 0.10 0.010   .   1.250 0.450 0.440 0.010 0.800 0.810   .
 80    5    21   0   7.2 270.0 32.0  65.0 57.00 22.00 0.10 0.01 0.040   .   1.150 0.350 0.240 0.110 0.800 0.910  9.0
 80    6     2   0   7.3 240.0 32.0  50.0 35.00 17.00 0.49 0.17 0.070 0.030 1.430 0.530 0.440 0.090 0.900 0.990  6.0
 80    6    19   0   7.6 310.0 30.0  63.0 57.00 17.00 0.02 0.00 0.340 0.020 1.430 0.630 0.530 0.100 0.800 0.900  9.8
 80    7     2   0   8.1 320.0 40.0  68.0 53.00 22.00 0.11 0.02 0.030 0.030 1.040 0.440 0.410 0.030 0.600 0.630 11.0
 80    7    31   0   7.3 240.0 31.0  55.0 38.00  8.00 0.16 0.01 0.060 0.060 0.980 0.580 0.580 0.000 0.400 0.400  7.6
 80   10    30   0   6.9 290.0 30.0  72.0 45.00 33.00 0.05 0.00 0.030 0.030 0.910 0.410 0.400 0.010 0.500 0.510 11.0
 80   11    13   0   6.8 230.0 18.0  56.0 40.00 19.00 0.22 0.02 0.060 0.040 2.500 1.700 1.680 0.020 0.800 0.820  8.2

LAKE=QUINSIGAMOND    STATION=Q16 MEDICAL SCHOOL DRAIN    TYPE=TRIBUTARY

YEAR MONTH DAY DEPTH PHU  CND   ALK   HDN   CLD   SO4   IRN  MNG   TLP   TDP   TLN   TKN   ORN   NH3   NO3   INN  SIL

 80    3     3   0   7.4 450.0 27.0 120.0 80.00 92.00 0.39 0.75 0.050   .   1.500 0.500 0.460 0.040 1.000 1.040  .
 80    4     8   0   7.3 210.0 20.0  43.0 40.00   .   0.00 0.04 0.020   .   1.350 0.850 0.870 0.080 0.400 0.480 2.7
 80    4    24   0   7.1 240.0 20.0  52.0 20.00 22.00 0.26 0.17 0.040   .   1.420 0.820 0.780 0.040 0.600 0.640 5.3
 80    5     6   0   7.3 260.0 22.0  62.0 43.00 36.00 0.15 0.26 0.000   .   1.310 0.510 0.500 0.010 0.800 0.810  .
 80    5    21   0   7.4 190.0 21.0  44.0 37.00 15.00 0.02 0.01 0.020   .   0.670 0.270 0.260 0.010 0.400 0.410 1.2
 80    6     2   0   7.3 340.0 29.0  67.0 20.00 36.00 0.21 0.58 0.070 0.010 1.170 0.270 0.210 0.060 0.900 0.960 8.0
 80    6    19   0   7.5 230.0 16.0  44.0 37.00 13.00 0.03 0.11 0.090 0.010 1.000 0.700 0.650 0.050 0.300 0.350 0.0
 80    7     2   0   7.1 210.0 22.0  42.0 36.00 14.00 0.02 0.02 0.040 0.020 1.030 0.730 0.550 0.180 0.300 0.480 0.0
 80    7    17   0   7.3 320.0 24.0  70.0 32.00 41.00 0.10 0.28 0.040 0.020 0.990 0.490 0.480 0.010 0.500 0.510 7.8
 80    7    31   0   7.4 270.0 25.0  68.0 49.00 14.00 0.10 0.09 0.040 0.040 1.130 0.730 0.660 0.070 0.400 0.470 4.4
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. LAKE QUINSIGAMOND AND FLINT POND CHEMICAL DATA FOR 1980

LAKE=QUINSIGAMOND   STATION=Q16 MEDICAL SCHOOL DRAIN   TYPE=TRIBUTARY

YEAR MONTH DAY DEPTH PHU  CND   ALK  HDN   CLD    SO4  IRN. MNG   TLP   TDP   TLN   TKN   ORN   NH3   NO3   INN  SIL

 80    8   18    0   7.8 220.0 20.0 51.0 41.00 17.00 0.06 0.06 0.010 0.010 0.690 0.590 0.580 0.010 0.100 0.110 1.4
 80    8   26    0   7.2 300.0 30.0 77.0 44.00 33.00 0.08 0.24 0.020 0.010 0.710 0.410 0.390 0.020 0.300 0.320 4.0
 80    9   16    0   7.1 340.0 30.0 89.0 60.00 36.00 0.08 0.04 0.050 0.050 0.650 0.450 0.420 0.030 0.200 0.230 0.5
 80    9   30    0   6.9 260.0 25.0 56.0 43.00 20.00 0.04 0.12 0.080 0.050 1.600 1.400 1.310 0.090 0.200 0.290 2.8
 80   10   30    0   6.9 210.0 25.0 50.0 40.00 14.00 0.00 0.04 0.040 0.010 0.630 0.430 0.390 0.040 0.200 0.240 3.5
 80   11   13    0   7.3 390.0 31.0 85.0 65.00 50.00 0.31 0.36 0.040 0.030 2.300 1.400 1.280 0.120 0.900 1.020 1.4

LAKE=QUINSIGAMOND   STATION=Q17 TILLY BROOK   TYPE=TRIBUTARY

YEAR MONTH DAY DEPTH PHU  CND   ALK  HDN   CLD    SO4  IRN  MNG   TLP   TDP   TLN   TKN   ORN   NH3   NO3   INN  SIL

 80    4    8    0   6.9 140.0  9.0 29.0 26.00   .   0.00 0.02 0.030   .   1.350 0.950 0.910 0.040 0.400 0.440 4.5
 80        24    0   7.0 150.0 12.0 30.0 15.00 14.00 0.51 0.11 0.020   .   1.160 0.960 0.910 0.050 0.200 0.250 2.2
 80    5    6    0   7.1 130.0 13.0 27.0 22.00 17.00 0.21 0.05 0.040   .   0.810 0.610 0.590 0.020 0.200 0.220   .
 80    5   21    0   7.2 130.0 14.0 28.0 26.00 10.00 0.28 0.03 0.060   .   0.430 0.330 0.240 0.090 0.100 0.190 1.2
 80    6    2    0   7.3 140.0 16.0 30.0 90.00  9.00 0.42 0.04 0.070 0.020 0.640 0.440 0.430 0.010 0.200 0.210 0.5
 00    6   19    0   7.3 165.0 18.0 35.0 27.00 11.00 0.31 0.09 0.070 0.010 1.260 0.960 0.920 0.040 0.300 0.340 0.2
 80    7    2    0   7.2 125.0 14.0 27.0 19.00  9.00 0.61 0.07 0.040 0.040 1.020 0.920 0.800 0.120 0.100 0.220 4.8
 80    7   17    0   7.3 210.0 29.0 42.0 61.00 18.00 0.25 0.03 0.030 0.020 1.530 0.730 0.710 0.020 0.800 0.820 5.6
 80    7   31    0   7.1 135.0 16.0 31.0 25.00  9.00 0.77 0.02 0.060 0.040 0.980 0.880 0.880 0.000 0.100 0.100 1.6
 80    8   18    0   7.4 210.0 34.0 47.0 36.00 13.00 0.08 0.03 0.010 0.010 0.970 0.570 0.550 0.020 0.400 0.420 2.5
 80    8   26    0   7.3 230.0 28.0 55.0 37.00 17.00 0.12 0.04 0.030 0.030 1.120 0.420 0.380 0.040 0.700 0.740 3.2
 80    9   16    0   6.8 220.0 27.0 50.0 38.00 16.00 0.08 0.03 0.100 0.050 1.090 0.690 0.430 0.260 0.400 0.660 0.1
 80    9   30    0   6.9 250.0 28.0 54.0 39.00 17.00 0.10 0.07 0.100 0.050 1.600 1.000 0.910 0.090 0.600 0.690 4.8
 80   10   30    0   6.8 170.0 14.0 44.0 27.00 22.00 0.14 0.01 0.030 0.020 1.070 0.870 0.850 0.020 0.200 0.220 7.6
 80   11   13    0   6.8 190.0 14.0 41.0 28.00 27.00 0.09 0.03 0.090 0.050 1.700 1.500 1.460 0.040 0.200 0.240 9.3

LAKE=QUINSIGAMOND   STATION=Q18 JORDAN POND OUTLET   TYPE=TRIBUTARY

YEAR MONTH DAY DEPTH PHU  CND   ALK  HDN   CLD    SO4  IRN  MNG   TLP   TDP   TLN   TKN   ORN   NH3   NO3   INN  SIL

 80    4   24    0   7.2 160.0 18.0 30.0 29.00 12.00 0.06 0.02 0.020   .   0.670 0.570 0.510 0.060 0.100 0.160 0.3
 80    5    6    0   7.3 160.0 36.0 29.0 28.00 14.00 0.13 0.04 0.040   .   0.660 0.560 0.530 0.030 0.100 0.130   .
 80    5   21    0   7.0 150.0 20.0 32.0 26.00 14.00 0.13 0.01 0.040   .   0.710 0.510 0.410 0.100 0.200 0.300 0.0
 80    7    2    0   7.1 150.0 19.0 28.0 25.00  7.00 0.20 0.02 0.040 0.010 0.640 0.840 0.540 0.100 0.000 0.100 0.0

LAKE=QUINSIGAMOND   STATION=Q19 BELMONT STREET DRAIN   TYPE=TRIBUTARY

YEAR MONTH DAY DEPTH PHU  CND   ALK    HDN    CLD   SO4  IRN  MNG   TLP   TDP   TLN   TKN   ORN   NH3   NO3   INN  SIL

 80    4   24    0   7.1 520.0 35.0   88.0  25.00 39.00 1.20 0.33 0.220   .   3.800 2.000 1.330 0.670 1.800 2.470 1.5
 80    5    6    0   7.2 480.0 13.0   99.0 100.00 45.00 0.82 0.58 0.300   .   3.150 1.350 0.890 0.460 1.800 2.260   .
 80    5   21    0   7.2 490.0 35.0   93.0 115.00 39.00 0.37 0.17 0.150   .   2.620 0.820 0.280 0.540 1.800 2.340 1.2
 80    6    2    0   7.3 330.0 30.0   63.0  90.00 23.00 2.40 0.61 0.800 0.240 4.150 2.950 1.950 1.000 1.200 2.200 6.0
 80    6   19    0   7.4 490.0 24.0   82.0  89.00 32.00 1.70 1.30 0.450 0.200 3.300 2.000 0.700 1.300 1.300 2.600 8.0
 80    7    2    0   7.2 260.0 24.0   51.0  46.00 17.00 0.09 0.06 0.080 0.040 1.390 0.890 0.730 0.160 0.500 0.660 2.4
 80    7   17    0   7.3 330.0 27.0   58.0  37.00 23.00 0.40 0.15 0.060 0.040 1.660 0.960 0.850 0.110 0.700 0.810 6.8
 80    7   31    0   6.9 250.0 21.0   53.0  47.00  9.00 0.84 0.22 0.110 0.050 2.000 1.200 1.040 0.160 0.800 0.960 4.6
 80    8   18    0   7.5 490.0 26.0   92.0  37.00 32.00 0.26 0.28 0.120 0.060 3.000 1.000 0.740 0.260 2.000 2.260 1.2
 80    8   26    0   7.3 460.0 29.0   87.0  91.00 27.00 0.57 0.66 0.240 0.090 2.400 1.100 0.740 0.360 1.300 1.660 1.1
 80    9   16    0   7.0 500.0 46.0   96.0 100.00 32.00 0.25 1.10 0.220 0.090 2.900 1.100 0.720 0.380 1.800 2.180 0.9
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LAKE QUINSIGAMOND AND FLINT POND CHEMICAL DATA FOR 1980

LAKE=QUINSIGAMOND STATION=Q19 BELMONT STREET DRAIN TYPE=TRIBUTARY

YEAR	MONTH	DAY	DEPTH	PHU	CND	ALK	HDN	CLD	SO4	IRN	MNG	TLP	TDP	TLN	TKN	ORN	NH3	NO3	INN	SIL
80	9	30	0	7.1	520.0	46.0	93.0	95.00	32.00	0.59	1.20	0.310	0.110	4.500	1.800	1.200	0.600	2.700	3.300	1.3
80	10	30	0	7.1	490.0	38.0	120.0	97.00	39.00	0.52	0.61	0.310	0.080	4.900	1.000	0.650	0.350	3.900	4.250	1.6
80	11	13	0	7.4	520.0	40.0	96.0	105.00	39.00	0.12	0.13	0.290	0.150	5.400	2.300	1.940	0.360	3.100	3.460	1.6

LAKE=QUINSIGAMOND STATION=Q20 CHANNEL BLW. BELMONT ST. DRAIN TYPE=TRIBUTARY

YEAR	MONTH	DAY	DEPTH	PHU	CND	ALK	HDN	CLD	SO4	IRN	MNG	TLP	TDP	TLN	TKN	ORN	NH3	NO3	INN	SIL
80	5	21	0	7.4	190.0	20.0	42.0	37.00	14.00	0.00	0.01	0.050	.	0.740	0.340	0.320	0.020	0.400	0.420	0.1
80	6	2	0	7.3	210.0	21.0	42.0	5.00	14.00	0.06	0.03	0.070	0.010	0.620	0.320	0.290	0.030	0.300	0.330	0.0
80	6	19	0	7.5	210.0	16.0	44.0	37.00	12.00	0.06	0.05	0.340	0.020	0.750	0.450	0.370	0.080	0.300	0.380	0.0
80	7	2	0	7.3	190.0	18.0	39.0	35.00	14.00	0.02	0.03	0.040	0.040	0.580	0.380	0.260	0.120	0.200	0.320	0.0
80	7	17	0	7.5	210.0	23.0	39.0	39.00	13.00	0.10	0.04	0.020	.	0.750	0.550	0.520	0.030	0.200	0.230	3.4
80	7	31	0	7.2	200.0	20.0	44.0	36.00	5.00	0.07	0.01	0.040	0.040	0.770	0.670	0.670	0.000	0.100	0.100	1.2
80	8	18	0	7.2	200.0	16.0	42.0	40.00	12.00	0.05	0.03	0.010	0.010	0.400	0.400	0.390	0.010	0.000	0.010	0.8
80	8	26	0	7.3	200.0	22.0	44.0	37.00	14.00	0.05	0.01	0.010	0.010	0.400	0.300	0.280	0.020	0.100	0.120	0.2
80	9	16	0	7.4	210.0	26.0	48.0	40.00	13.00	0.00	0.00	0.060	0.030	0.400	0.300	0.290	0.010	0.100	0.110	2.7
80	9	30	0	7.1	215.0	23.0	45.0	39.00	13.00	0.03	0.10	0.080	0.050	0.710	0.510	0.340	0.170	0.200	0.370	1.8
80	10	30	0	7.0	210.0	24.0	47.0	40.00	11.00	0.03	0.06	0.360	0.040	0.890	0.790	0.620	0.170	0.100	0.270	3.0
80	11	13	0	7.3	220.0	29.0	47.0	38.00	11.00	0.37	0.25	0.110	0.040	2.300	2.200	1.770	0.430	0.100	0.530	3.7

Appendix B

Data Summary by Station and Depth Interval

Depth Categories:
Surface: Depth < 30 feet
Bottom : Depth >= 30 feet

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DATA SUMMARY BY STATION AND DEPTH

---------------------------------- STATION CODE=F01 POND, 800 FT SO. INLET   DEPTH INTERVAL=SURFACE ----------------------------------

VARIAB		N	MEAN	STD	MIN	P25	MEDIAN	P75	MAX
DISSOLVED OXYGEN	MG/L	67	8.825	1.733	5.500	7.600	8.800	9.800	12.100
TEMPERATURE	DEG. C	69	17.877	6.626	1.000	13.800	19.400	23.250	28.500
CHLOROPHYLL-A	MG/M3	10	4.917	1.993	1.900	3.217	4.940	6.847	7.910
TOTAL ALGAE	CELLS/ML	11	1836.718	1895.667	646.300	843.000	1517.400	1826.500	7390.297
BLUE GREEN ALGAE	CELLS/ML	11	178.818	246.023	0.000	0.000	56.200	449.600	646.300
DIATOMS	CELLS/ML	11	1338.582	1955.900	0.000	224.800	786.800	1545.500	6996.898
FLAGELLATES	CELLS/ML	11	224.800	107.370	56.200	112.400	252.900	309.100	393.400
GREEN ALGAE	CELLS/ML	11	94.518	160.083	0.000	0.000	28.100	84.300	477.700
CONDUCTIVITY	UHOS/CM	35	204.571	10.667	170.000	200.000	210.000	210.000	220.000
ALKALINITY	MG/L	35	22.314	2.687	17.000	21.000	22.000	24.000	30.000
HARDNESS	MG/L	35	44.000	2.787	36.000	42.000	44.000	45.000	49.000
PH	STD. UNITS	35	7.320	0.376	6.200	7.100	7.300	7.400	8.200
CHLORIDE	MG/L	34	38.382	2.965	29.000	37.000	39.000	40.000	43.000
SULFATE	MG/L	33	12.515	2.210	6.000	12.000	12.000	14.000	17.000
IRON	MG/L	35	0.069	0.052	0.000	0.030	0.050	0.110	0.210
MANGANESE	MG/L	35	0.059	0.044	0.010	0.020	0.050	0.090	0.180
TOTAL NITROGEN	MG/L	35	0.753	0.279	0.370	0.530	0.690	0.910	1.600
TOTAL KJELDAHL N	MG/L	35	0.579	0.209	0.300	0.400	0.540	0.750	1.200
ORGANIC N	MG/L	35	0.528	0.207	0.260	0.350	0.490	0.680	1.150
AMMONIA-N	MG/L	35	0.051	0.034	0.000	0.030	0.050	0.070	0.150
NITRATE-N	MG/L	35	0.175	0.217	0.000	0.000	0.100	0.300	0.800
INORGANIC N	MG/L	35	0.225	0.220	0.000	0.050	0.160	0.380	0.870
TOTAL P	MG/L	35	0.045	0.020	0.010	0.030	0.040	0.060	0.090
TOTAL DISSOLVED P	MG/L	25	0.028	0.012	0.010	0.020	0.030	0.040	0.050
SILICA	MG/L	33	1.961	1.241	0.000	1.050	2.200	2.950	3.800
APPARENT COLOR	PT-CO UNITS	28	20.893	10.188	5.000	15.000	20.000	30.000	40.000
SECCHI DEPTH	FT	12	7.050	1.585	4.600	5.400	7.250	8.450	9.200
TOTAL SOLIDS	MG/L	35	156.400	63.063	62.000	114.000	150.000	194.000	388.000
SUSP.SOLIDS	MG/L	35	2.626	1.399	0.500	2.000	2.000	3.000	6.500
TOTAL COLIFORMS	COUNTS/100 ML	13	122.308	324.452	10.000	15.000	30.000	50.000	1200.000
FECAL COLIFORMS	COUNTS/100 ML	13	6.154	2.193	5.000	5.000	5.000	7.500	10.000
FECAL STREP	COUNTS/100 ML	12	5.417	1.443	5.000	5.000	5.000	5.000	10.000

---------------------------------- STATION CODE=F02 POND, 1500 FT NO. RT.20   DEPTH INTERVAL=SURFACE ----------------------------------

VARIAB		N	MEAN	STD	MIN	P25	MEDIAN	P75	MAX
DISSOLVED OXYGEN	MG/L	14	9.171	1.353	7.500	8.075	8.700	10.050	11.800
TEMPERATURE	DEG. C	14	17.950	7.061	7.500	13.075	17.750	23.750	29.000
CONDUCTIVITY	UHOS/CM	14	203.571	9.208	190.000	197.500	205.000	210.000	220.000
ALKALINITY	MG/L	14	22.571	1.651	20.000	21.750	22.000	24.000	26.000
HARDNESS	MG/L	14	44.429	2.277	41.000	43.500	44.000	45.000	49.000
PH	STD. UNITS	14	7.393	0.240	7.100	7.200	7.350	7.525	8.000
CHLORIDE	MG/L	14	38.143	2.413	35.000	36.000	37.500	39.500	43.000
SULFATE	MG/L	13	12.231	2.488	6.000	11.000	12.000	13.500	17.000
IRON	MG/L	14	0.076	0.070	0.000	0.037	0.070	0.085	0.250
MANGANESE	MG/L	14	0.065	0.043	0.020	0.020	0.055	0.092	0.160
TOTAL NITROGEN	MG/L	14	0.676	0.240	0.370	0.517	0.625	0.795	1.200
TOTAL KJELDAHL N	MG/L	14	0.569	0.188	0.360	0.387	0.550	0.700	0.900
ORGANIC N	MG/L	14	0.527	0.187	0.300	0.377	0.495	0.685	0.870
AMMONIA-N	MG/L	14	0.041	0.027	0.000	0.010	0.050	0.062	0.070
NITRATE-N	MG/L	14	0.107	0.138	0.000	0.000	0.050	0.225	0.400
INORGANIC N	MG/L	14	0.149	0.152	0.000	0.010	0.105	0.277	0.470

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                                DATA SUMMARY BY STATION AND DEPTH

----------------------------- STATION CODE=F02 POND, 1500 FT NO. RT.20   DEPTH INTERVAL=SURFACE -----------------------------------

  VARIAB                                N        MEAN         STD         MIN         P25      MEDIAN         P75         MAX

  TOTAL P             MG/L             14       0.039       0.018       0.010       0.030       0.040       0.042       0.090
  TOTAL DISSOLVED P   MG/L              9       0.027       0.014       0.010       0.015       0.020       0.040       0.050
  SILICA              MG/L             13       2.054       1.015       0.000       1.250       2.200       3.000       3.300
  APPARENT COLOR      PT-CO UNITS      11      20.000      10.000       5.000      10.000      20.000      30.000      30.000
  TOTAL SOLIDS        MG/L             14     132.286      25.027      78.000     121.500     133.000     150.500     182.000
  SUSP.SOLIDS         MG/L             14       2.250       1.252       0.500       1.375       2.000       3.125       4.500
  TOTAL COLIFORMS     COUNTS/100 ML    13      77.308     127.510       5.000      10.000      30.000     105.000     470.000
  FECAL COLIFORMS     COUNTS/100 ML    13       7.692       5.633       5.000       5.000       5.000       7.500      20.000
  FECAL STREP         COUNTS/100 ML    12       5.000       0.000       5.000       5.000       5.000       5.000       5.000

----------------------------- STATION CODE=F03 POND, 2000 FT SO. RT.20   DEPTH INTERVAL=SURFACE -----------------------------------

VARIAB                                  N        MEAN         STD         MIN         P25      MEDIAN         P75         MAX

DISSOLVED OXYGEN      MG/L             64       8.628       1.601       4.800       7.800       8.600       9.775      11.600
TEMPERATURE           DEG. C           64      17.798       6.624       6.500      13.800      18.000      23.000      28.500
CHLOROPHYLL-A         MG/M3            10       4.826       2.311       1.760       3.320       4.150       6.022       9.550
TOTAL ALGAE           CELLS/ML         12    1189.566    1304.338     252.900     456.625     576.050    1770.300    4018.300
BLUE GREEN ALGAE      CELLS/ML         12     154.550     152.740       0.000      56.200      84.300     281.000     505.800
DIATOMS               CELLS/ML         12     782.116    1283.115       0.000       7.025     126.450    1517.400    3737.300
FLAGELLATES           CELLS/ML         12     117.083     173.565       0.000      14.050      84.300     112.400     646.300
GREEN ALGAE           CELLS/ML         12     135.817     109.050       0.000      56.200      98.350     196.700     393.400
CONDUCTIVITY          UHOS/CM          34     223.824      10.449     210.000     217.500     220.000     230.000     240.000
ALKALINITY            MG/L             34      25.765       3.394      20.000      23.000      25.500      28.250      31.000
HARDNESS              MG/L             34      47.000       2.850      40.000      44.750      48.000      48.250      52.000
PH                    STD. UNITS       34       7.356       0.137       7.100       7.300       7.300       7.400       7.700
CHLORIDE              MG/L             34      43.000       1.537      39.000      42.000      43.000      44.000      46.000
SULFATE               MG/L             32      12.125       2.904       5.000      10.000      12.000      14.000      17.000
IRON                  MG/L             34       0.084       0.055       0.000       0.047       0.080       0.122       0.240
MANGANESE             MG/L             34       0.073       0.099       0.000       0.030       0.045       0.082       0.500
TOTAL NITROGEN        MG/L             34       0.723       0.244       0.310       0.532       0.715       0.872       1.500
TOTAL KJELDAHL N      MG/L             34       0.623       0.208       0.300       0.450       0.625       0.770       1.200
ORGANIC N             MG/L             34       0.566       0.207       0.210       0.425       0.600       0.683       1.180
AMMONIA-N             MG/L             34       0.057       0.039       0.000       0.027       0.060       0.075       0.160
NITRATE-N             MG/L             34       0.100       0.110       0.000       0.000       0.100       0.200       0.300
INORGANIC N           MG/L             34       0.157       0.119       0.000       0.050       0.180       0.260       0.370
TOTAL P               MG/L             34       0.055       0.032       0.010       0.030       0.050       0.060       0.140
TOTAL DISSOLVED P     MG/L             24       0.193       0.557       0.010       0.020       0.030       0.047       2.000
SILICA                MG/L             32       2.128       1.387       0.000       0.700       2.200       3.475       4.200
APPARENT COLOR        PT-CO UNITS      28      19.643       9.421       5.000      15.000      20.000      28.750      35.000
SECCHI DEPTH          FT               12       6.100       1.613       3.900       4.750       6.250       7.125       9.200
TOTAL SOLIDS          MG/L             34     179.941     105.548      80.000     132.000     153.000     208.000     730.000
SUSP.SOLIDS           MG/L             34       3.559       1.902       0.000       2.000       3.500       5.000       8.000
TOTAL COLIFORMS       COUNTS/100 ML    12      42.500      49.932      10.000      10.000      15.000      75.000     160.000
FECAL COLIFORMS       COUNTS/100 ML    12       7.083       5.823       5.000       5.000       5.000       5.000      25.000
FECAL STREP           COUNTS/100 ML    11       5.000       0.000       5.000       5.000       5.000       5.000       5.000
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                                        DATA SUMMARY BY STATION AND DEPTH
------------------------------ STATION CODE=F04 POND, 1500 FT WEST IRISH DAM   DEPTH INTERVAL=SURFACE ------------------------------

VARIAB                                   N       MEAN        STD        MIN        P25     MEDIAN        P75        MAX

DISSOLVED OXYGEN     MG/L               14      8.843      1.068      7.300      8.100      8.500      9.625     11.100
TEMPERATURE          DEG. C             14     17.786      7.104      5.500     13.225     17.750     23.250     29.000
CHLOROPHYLL-A        MG/M3              10      3.196      1.212      0.810      2.805      3.115      3.632      5.400
TOTAL ALGAE          CELLS/ML           11    641.191   1081.964    112.400    196.700    224.800    421.500   3793.500
BLUE GREEN ALGAE     CELLS/ML           11     15.327     26.251      0.000      0.000      0.000     28.100     84.300
DIATOMS              CELLS/ML           11    436.827   1037.218      0.000      0.000     28.100    252.900   3484.400
FLAGELLATES          CELLS/ML           11    153.273    100.819      0.000     84.300    140.500    224.800    309.100
GREEN ALGAE          CELLS/ML           11     35.764     28.354      0.000     28.100     28.100     56.200     84.300
CONDUCTIVITY         UHOS/CM            14    215.714     19.499    190.000    200.000    210.000    222.500    270.000
ALKALINITY           MG/L               14     24.429      3.345     18.000     23.000     24.000     25.000     32.000
HARDNESS             MG/L               14     45.071      3.452     40.000     43.000     44.000     45.750     53.000
PH                   STD. UNITS         14      7.357      0.145      7.100      7.275      7.300      7.500      7.600
CHLORIDE             MG/L               14     42.429      3.817     37.000     40.000     41.500     43.250     53.000
SULFATE              MG/L               13     12.385      3.176      6.000     10.000     12.000     14.000     18.000
IRON                 MG/L               14      0.064      0.045      0.000      0.027      0.060      0.100      0.140
MANGANESE            MG/L               14      0.076      0.049      0.020      0.037      0.070      0.112      0.170
TOTAL NITROGEN       MG/L               14      0.683      0.238      0.360      0.492      0.645      0.872      1.150
TOTAL KJELDAHL N     MG/L               14      0.583      0.173      0.330      0.422      0.590      0.715      0.850
ORGANIC N            MG/L               14      0.531      0.166      0.260      0.367      0.570      0.665      0.780
AMMONIA-N            MG/L               14      0.051      0.034      0.000      0.017      0.060      0.070      0.100
NITRATE-N            MG/L               14      0.100      0.124      0.000      0.000      0.050      0.225      0.300
INORGANIC N          MG/L               14      0.151      0.142      0.000      0.027      0.100      0.292      0.400
TOTAL P              MG/L               14      0.046      0.027      0.020      0.030      0.040      0.050      0.110
TOTAL DISSOLVED P    MG/L                9      0.022      0.012      0.010      0.015      0.020      0.025      0.050
SILICA               MG/L               13      1.808      1.104      0.000      1.100      2.000      2.800      3.500
APPARENT COLOR       PT-CO UNITS        11     22.273      7.862      5.000     20.000     25.000     25.000     35.000
TOTAL SOLIDS         MG/L               14    150.714     32.613     98.000    125.500    140.000    185.500    203.000
SUSP.SOLIDS          MG/L               14      2.214      1.087      0.500      1.375      2.250      2.750      4.000
TOTAL COLIFORMS      COUNTS/100 ML      12    128.333    168.837     10.000     20.000     35.000    232.500    500.000
FECAL COLIFORMS      COUNTS/100 ML      12      7.083      3.343      5.000      5.000      5.000     10.000     15.000
FECAL STREP          COUNTS/100 ML      10      7.000      4.830      5.000      5.000      5.000      6.250     20.000

--------------------------------- STATION CODE=F05 POND, @ RT.20 BRIDGE   DEPTH INTERVAL=SURFACE ---------------------------------

VARIAB                                   N       MEAN        STD        MIN        P25     MEDIAN        P75        MAX

DISSOLVED OXYGEN     MG/L               14      8.695      1.441      5.800      7.775      8.600      9.400     11.300
TEMPERATURE          DEG. C             14     17.750      7.225      5.500     13.075     17.750     23.250     29.000
CONDUCTIVITY         UHOS/CM            13    207.692     15.892    180.000    195.000    210.000    220.000    240.000
ALKALINITY           MG/L               13     24.000      2.550     21.000     22.000     23.000     25.000     30.000
HARDNESS             MG/L               13     43.769      4.729     34.000     43.000     45.000     46.500     51.000
PH                   STD. UNITS         13      7.346      0.215      7.000      7.150      7.400      7.450      7.700
CHLORIDE             MG/L               13     37.923      2.813     34.000     35.500     37.000     40.500     43.000
SULFATE              MG/L               12     12.167      2.949      6.000     10.250     12.000     13.750     18.000
IRON                 MG/L               13      0.062      0.045      0.000      0.025      0.060      0.100      0.150
MANGANESE            MG/L               13      0.066      0.065      0.000      0.020      0.060      0.090      0.240
TOTAL NITROGEN       MG/L               13      0.711      0.226      0.270      0.570      0.660      0.950      1.030
TOTAL KJELDAHL N     MG/L               13      0.603      0.186      0.270      0.490      0.630      0.660      0.950
ORGANIC N            MG/L               13      0.553      0.199      0.190      0.445      0.580      0.620      0.950
AMMONIA-N            MG/L               13      0.050      0.024      0.000      0.035      0.050      0.070      0.080
NITRATE-N            MG/L               13      0.108      0.161      0.000      0.000      0.000      0.250      0.400
INORGANIC N          MG/L               13      0.158      0.169      0.000      0.035      0.080      0.320      0.460
TOTAL P              MG/L               13      0.047      0.029      0.010      0.025      0.040      0.055      0.110
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                                    DATA SUMMARY BY STATION AND DEPTH
------------------------------- STATION CODE=F05 POND, @ RT.20 BRIDGE   DEPTH INTERVAL=SURFACE --------------------------------

  VARIAB                                N         MEAN          STD          MIN          P25       MEDIAN          P75          MAX

  TOTAL DISSOLVED P    MG/L             8        0.022        0.014        0.010        0.010        0.020        0.037        0.040
  SILICA               MG/L            12        2.408        1.559        0.000        1.275        2.000        4.025        5.000
  APPARENT COLOR       PT-CO UNITS     10       23.500        8.515       10.000       17.500       25.000       30.000       35.000
  TOTAL SOLIDS         MG/L            13      137.846       19.399       92.000      129.000      136.000      148.000      172.000
  SUSP.SOLIDS          MG/L            13        3.000        1.443        0.000        2.000        3.000        4.000        5.500
  TOTAL COLIFORMS      COUNTS/100 ML   14      219.286      250.183       30.000       40.000      175.000      285.000     1000.000
  FECAL COLIFORMS      COUNTS/100 ML   14       41.071       50.580        5.000        8.750       25.000       50.000      160.000
  FECAL STREP          COUNTS/100 ML   11       10.909       11.362        5.000        5.000        5.000       10.000       40.000

------------------------------- STATION CODE=F06 SOUTH MEADOW BROOK   DEPTH INTERVAL=SURFACE --------------------------------

  VARIAB                                N         MEAN          STD          MIN          P25       MEDIAN          P75          MAX

  DISSOLVED OXYGEN     MG/L            16        6.894        2.144        2.600        5.200        7.200        8.900       10.100
  TEMPERATURE          DEG. C          16       12.969        7.201        1.000        7.700       13.500       19.000       23.000
  CONDUCTIVITY         UHOS/CM         16      207.500       27.689      150.000      195.000      215.000      220.000      250.000
  ALKALINITY           MG/L            16       25.188        3.229       18.000       22.250       26.000       27.750       30.000
  HARDNESS             MG/L            16       51.313       10.738       18.000       48.250       54.500       57.750       63.000
  PH                   STD. UNITS      16        6.994        0.267        6.600        6.700        7.000        7.100        7.500
  CHLORIDE             MG/L            16       34.250        7.416       18.000       30.750       34.500       40.750       44.000
  SULFATE              MG/L            15       16.067        2.963       11.000       14.000       16.000       18.000       22.000
  IRON                 MG/L            16        0.247        0.184        0.000        0.112        0.190        0.395        0.600
  MANGANESE            MG/L            16        0.054        0.043        0.000        0.022        0.050        0.077        0.170
  TOTAL NITROGEN       MG/L            16        1.906        0.600        1.100        1.535        1.850        2.100        3.500
  TOTAL KJELDAHL N     MG/L            16        0.812        0.428        0.300        0.537        0.730        0.832        2.000
  ORGANIC N            MG/L            16        0.744        0.430        0.260        0.505        0.630        0.775        1.960
  AMMONIA-N            MG/L            16        0.067        0.040        0.020        0.040        0.055        0.097        0.150
  NITRATE-N            MG/L            16        1.094        0.375        0.300        0.925        1.100        1.300        1.900
  INORGANIC N          MG/L            16        1.161        0.390        0.320        0.950        1.150        1.387        2.000
  TOTAL P              MG/L            16        0.090        0.076        0.020        0.042        0.055        0.107        0.270
  TOTAL DISSOLVED P    MG/L            10        0.035        0.016        0.010        0.020        0.035        0.050        0.060
  SILICA               MG/L            14        6.629        3.706        1.100        3.200        8.150        9.225       12.000
  APPARENT COLOR       PT-CO UNITS     12       22.500       16.167        0.000        7.500       22.500       30.000       60.000
  TOTAL SOLIDS         MG/L            16      176.375      135.779      102.000      122.500      144.000      162.000      676.000
  SUSP.SOLIDS          MG/L            16        4.031        3.779        1.000        1.125        2.250        5.500       15.000
  TOTAL COLIFORMS      COUNTS/100 ML   16      767.500     1279.367       10.000      200.000      310.000      522.500     5000.000
  FECAL COLIFORMS      COUNTS/100 ML   16       85.938       64.555        5.000       26.250       80.000      130.000      200.000
  FECAL STREP          COUNTS/100 ML   12       44.250       71.956        5.000        6.250       20.000       30.000      250.000

------------------------------- STATION CODE=F07 INLET FROM LK. QUINS.   DEPTH INTERVAL=SURFACE --------------------------------

  VARIAB                                N         MEAN          STD          MIN          P25       MEDIAN          P75          MAX

  DISSOLVED OXYGEN     MG/L            16        9.925        2.034        7.000        8.600        9.500       11.575       14.400
  TEMPERATURE          DEG. C          16       16.325        8.218        1.100        8.500       17.250       23.750       27.000
  CONDUCTIVITY         UHOS/CM         15      224.333       21.453      210.000      210.000      220.000      230.000      290.000
  ALKALINITY           MG/L            15       23.467        2.066       21.000       22.000       23.000       26.000       27.000
  HARDNESS             MG/L            15       46.133        4.704       38.000       44.000       44.000       49.000       59.000
  PH                   STD. UNITS      15        7.340        0.184        7.000        7.200        7.300        7.500        7.700
  CHLORIDE             MG/L            15       43.133        6.854       35.000       38.000       41.000       46.000       56.000
  SULFATE              MG/L            14       13.571        2.929       10.000       10.750       13.500       15.500       19.000
  IRON                 MG/L            15        0.101        0.120        0.000        0.020        0.070        0.150        0.450
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DATA SUMMARY BY STATION AND DEPTH

STATION CODE=F07 INLET FROM LK. QUINS. DEPTH INTERVAL=SURFACE

VARIAB		N	MEAN	STD	MIN	P25	MEDIAN	P75	MAX
MANGANESE	MG/L	15	0.059	0.034	0.020	0.030	0.050	0.100	0.110
TOTAL NITROGEN	MG/L	15	1.069	0.540	0.420	0.680	1.010	1.150	2.450
TOTAL KJELDAHL N	MG/L	15	0.735	0.344	0.300	0.470	0.670	0.880	1.600
ORGANIC N	MG/L	15	0.656	0.333	0.200	0.410	0.640	0.810	1.410
AMMONIA-N	MG/L	15	0.079	0.062	0.030	0.040	0.070	0.070	0.250
NITRATE-N	MG/L	15	0.333	0.481	0.000	0.100	0.200	0.400	2.000
INORGANIC N	MG/L	15	0.413	0.527	0.030	0.170	0.350	0.430	2.250
TOTAL P	MG/L	14	0.056	0.039	0.010	0.027	0.050	0.085	0.140
TOTAL DISSOLVED P	MG/L	9	0.022	0.013	0.010	0.010	0.020	0.035	0.040
SILICA	MG/L	13	2.123	1.718	0.000	0.500	1.800	3.700	4.600
APPARENT COLOR	PT-CO UNITS	11	18.636	11.851	10.000	10.000	15.000	25.000	50.000
TOTAL SOLIDS	MG/L	15	168.400	37.211	108.000	140.000	158.000	204.000	226.000
SUSP. SOLIDS	MG/L	15	2.833	2.185	0.000	2.000	2.500	4.500	8.000
TOTAL COLIFORMS	COUNTS/100 ML	16	104.375	142.640	10.000	15.000	50.000	130.000	550.000
FECAL COLIFORMS	COUNTS/100 ML	16	15.938	24.029	5.000	5.000	5.000	10.000	90.000
FECAL STREP	COUNTS/100 ML	12	8.750	10.028	5.000	5.000	5.000	8.750	40.000

STATION CODE=F08 IRISH DAM OUTLET DEPTH INTERVAL=SURFACE

VARIAB		N	MEAN	STD	MIN	P25	MEDIAN	P75	MAX
DISSOLVED OXYGEN	MG/L	16	8.362	2.158	3.700	7.275	8.050	10.150	12.600
TEMPERATURE	DEG. C	16	16.369	8.813	0.000	8.575	18.000	23.750	27.000
CONDUCTIVITY	UHOS/CM	16	225.313	28.605	190.000	210.000	212.500	227.500	290.000
ALKALINITY	MG/L	16	25.563	4.953	15.000	24.000	25.000	27.750	39.000
HARDNESS	MG/L	16	45.750	6.181	37.000	43.000	44.500	45.000	64.000
PH	STD. UNITS	16	7.287	0.175	6.800	7.225	7.300	7.400	7.500
CHLORIDE	MG/L	16	43.438	6.033	37.000	39.000	41.500	47.250	55.000
SULFATE	MG/L	15	13.133	3.021	9.000	11.000	13.000	14.000	21.000
IRON	MG/L	16	0.089	0.096	0.000	0.042	0.060	0.097	0.370
MANGANESE	MG/L	16	0.099	0.125	0.000	0.025	0.060	0.120	0.530
TOTAL NITROGEN	MG/L	16	0.959	0.443	0.410	0.632	0.835	1.260	2.140
TOTAL KJELDAHL N	MG/L	16	0.728	0.275	0.370	0.477	0.710	0.862	1.300
ORGANIC N	MG/L	16	0.654	0.274	0.170	0.420	0.695	0.777	1.220
AMMONIA-N	MG/L	16	0.074	0.068	0.000	0.030	0.065	0.087	0.250
NITRATE-N	MG/L	16	0.231	0.330	0.000	0.000	0.100	0.300	1.300
INORGANIC N	MG/L	16	0.306	0.360	0.000	0.042	0.175	0.385	1.370
TOTAL P	MG/L	16	0.050	0.021	0.020	0.030	0.050	0.060	0.090
TOTAL DISSOLVED P	MG/L	10	0.037	0.044	0.010	0.017	0.030	0.030	0.160 ←
SILICA	MG/L	14	1.536	1.046	0.000	0.750	1.350	2.550	3.200
APPARENT COLOR	PT-CO UNITS	12	19.583	9.643	10.000	11.250	17.500	23.750	40.000
TOTAL SOLIDS	MG/L	16	168.875	50.538	102.000	133.000	153.000	212.500	272.000
SUSP. SOLIDS	MG/L	16	2.375	1.544	0.500	1.125	2.000	3.375	6.500
TOTAL COLIFORMS	COUNTS/100 ML	16	66.875	80.060	10.000	20.000	30.000	90.000	260.000
FECAL COLIFORMS	COUNTS/100 ML	16	6.250	2.236	5.000	5.000	5.000	8.750	10.000
FECAL STREP	COUNTS/100 ML	12	12.083	21.581	5.000	5.000	5.000	5.000	80.000

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                                        DATA SUMMARY BY STATION AND DEPTH
------------------------------- STATION CODE=F09 BONNIE BROOK   DEPTH INTERVAL=SURFACE -----------------------------------
VARIAB
                                           N        MEAN          STD          MIN          P25       MEDIAN          P75          MAX

DISSOLVED OXYGEN      MG/L                14        8.157        1.256        6.300        7.500        7.900        9.150       11.000
TEMPERATURE           DEG. C              14       18.536        5.846       10.000       13.250       21.000       23.000       27.000
CONDUCTIVITY          UHOS/CM             13      464.231       98.612      385.000      410.000      440.000      485.000      770.000
ALKALINITY            MG/L                13       31.462        7.795       25.000       27.500       29.000       30.500       53.000
HARDNESS              MG/L                13       73.231       12.146       62.000       67.000       70.000       76.500      110.000
PH                    STD. UNITS          13        7.331        0.250        6.900        7.150        7.300        7.550        7.700
CHLORIDE              MG/L                13       89.615       21.658       41.000       77.000       90.000      110.000      115.000
SULFATE               MG/L                13       29.462       19.932       11.000       21.500       25.000       28.000       93.000
IRON                  MG/L                13        0.415        0.273        0.070        0.140        0.430        0.675        0.800
MANGANESE             MG/L                13        0.162        0.114        0.000        0.055        0.180        0.250        0.350
TOTAL NITROGEN        MG/L                13        2.055        3.539        0.210        0.915        1.130        1.460       13.770
TOTAL KJELDAHL N      MG/L                13        0.670        0.212        0.210        0.515        0.740        0.825        0.930
ORGANIC N             MG/L                13        0.605        0.232        0.090        0.445        0.650        0.750        0.900
AMMONIA-N             MG/L                13        0.065        0.038        0.020        0.030        0.060        0.105        0.120
NITRATE-N             MG/L                13        1.385        3.495        0.000        0.300        0.500        0.600       13.000
INORGANIC N           MG/L                13        1.450        3.465        0.120        0.325        0.600        0.690       13.030
TOTAL P               MG/L                13        0.055        0.034        0.020        0.035        0.050        0.065        0.150
TOTAL DISSOLVED P     MG/L                 9        0.036        0.009        0.020        0.030        0.040        0.040        0.050
SILICA                MG/L                12        7.467        2.583        1.200        6.050        7.600        9.500       11.000
APPARENT COLOR        PT-CO UNITS         11       19.091       12.613        5.000       10.000       15.000       30.000       45.000
TOTAL SOLIDS          MG/L                13      301.077       89.563      224.000      245.000      280.000      320.000      572.000
SUSP.SOLIDS           MG/L                13        6.692        3.320        2.500        4.250        6.000        7.750       15.000
TOTAL COLIFORMS       COUNTS/100 ML       12     1935.000     2621.396       20.000      310.000      580.000     3350.000     9000.000
FECAL COLIFORMS       COUNTS/100 ML       12      142.083      134.763        5.000       42.500       90.000      262.500      400.000
FECAL STREP           COUNTS/100 ML       11       41.364       53.343        5.000        5.000       30.000       40.000      180.000

------------------------------- STATION CODE=Q01 LAKE, 600 FT SO. I-290   DEPTH INTERVAL=SURFACE -------------------------
VARIAB
                                           N        MEAN          STD          MIN          P25       MEDIAN          P75          MAX

DISSOLVED OXYGEN      MG/L                44        9.441        1.711        5.900        8.400        9.150       10.350       14.300
TEMPERATURE           DEG. C              82       16.071        5.939        6.000       11.000       16.500       21.125       27.000
CHLOROPHYLL-A         MG/M3               13        4.300        1.618        2.030        3.115        3.740        5.605        7.060
TOTAL ALGAE           CELLS/ML            14     2042.150     2705.425      281.000      579.150      828.950     2472.800     9694.500
BLUE GREEN ALGAE      CELLS/ML            14      228.814      201.688        0.000       49.175      196.700      421.500      590.100
DIATOMS               CELLS/ML            14     1625.785     2768.381        0.000       49.175      309.100     2023.200     9441.598
FLAGELLATES           CELLS/ML            14      124.886       67.925       28.100       71.800      126.450      175.625      224.800
GREEN ALGAE           CELLS/ML            14       59.093       73.617        0.000        0.000       28.100       91.325      265.300
CONDUCTIVITY          UHOS/CM             25      195.600        8.699      180.000      190.000      190.000      200.000      210.000
ALKALINITY            MG/L                25       21.560        3.056       17.000       20.000       21.000       22.000       33.000
HARDNESS              MG/L                25       42.280        2.112       38.000       41.000       42.000       44.000       47.000
PH                    STD. UNITS          25        7.264        0.253        6.900        7.100        7.200        7.300        8.300
CHLORIDE              MG/L                25       37.480        2.663       33.000       36.000       37.000       39.000       45.000
SULFATE               MG/L                23       12.261        2.562        4.000       12.000       13.000       14.000       15.000
IRON                  MG/L                25        0.087        0.101        0.000        0.035        0.060        0.100        0.490
MANGANESE             MG/L                25        0.037        0.074        0.000        0.010        0.020        0.035        0.380
TOTAL NITROGEN        MG/L                25        0.896        0.459        0.360        0.575        0.830        1.030        2.380
TOTAL KJELDAHL N      MG/L                25        0.588        0.306        0.260        0.380        0.530        0.650        1.600
ORGANIC N             MG/L                25        0.545        0.268        0.260        0.350        0.490        0.630        1.340
AMMONIA-N             MG/L                25        0.043        0.054        0.000        0.010        0.030        0.055        0.260
NITRATE-N             MG/L                25        0.308        0.380        0.000        0.100        0.300        0.400        2.000
INORGANIC N           MG/L                25        0.351        0.384        0.010        0.160        0.340        0.415        2.030
TOTAL P               MG/L                25        0.102        0.135        0.010        0.020        0.050        0.095        0.490
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                                   DATA SUMMARY BY STATION AND DEPTH

------------------------------- STATION CODE=Q01 LAKE, 600 FT SO. I-290   DEPTH INTERVAL=SURFACE ----------------------------------

    VARIAB                                N        MEAN         STD        MIN         P25      MEDIAN         P75         MAX

    TOTAL DISSOLVED P    MG/L            18       0.021       0.015      0.000       0.010       0.015       0.032       0.050
    SILICA               MG/L            23       1.078       0.988      0.000       0.200       0.900       1.600       3.600
    APPARENT COLOR       PT-CO UNITS     21      15.238      10.183      0.000       7.500      15.000      20.000      40.000
    SECCHI DEPTH         FT              15       8.553       3.137      5.300       5.800       7.500      11.200      15.200
    TOTAL SOLIDS         MG/L            25     148.512      46.308     18.800     120.000     134.000     186.000     244.000
    SUSP.SOLIDS          MG/L            25       1.640       1.454      0.000       0.500       1.500       2.750       5.000
    TOTAL COLIFORMS      COUNTS/100 ML   15     134.667     174.555     10.000      40.000      40.000     180.000     620.000
    FECAL COLIFORMS      COUNTS/100 ML   15      17.667      18.504      5.000       5.000      10.000      30.000      60.000
    FECAL STREP          COUNTS/100 ML   15       8.000       7.270      5.000       5.000       5.000       5.000      30.000

------------------------------- STATION CODE=Q01 LAKE, 600 FT SO. I-290   DEPTH INTERVAL=BOTTOM -----------------------------------

    VARIAB                                N        MEAN         STD        MIN         P25      MEDIAN         P75         MAX

    DISSOLVED OXYGEN     MG/L           100       4.949       3.900      0.000       0.850       5.150       7.900      11.800
    TEMPERATURE          DEG. C         172       7.262       1.207      5.000       7.000       7.000       7.500      12.000
    CONDUCTIVITY         UHOS/CM         28     212.500      10.758    200.000     210.000     210.000     220.000     240.000
    ALKALINITY           MG/L            28      29.607       9.957     20.000      23.250      27.000      30.750      57.000
    HARDNESS             MG/L            28      44.714       3.287     40.000      42.000      44.000      47.750      54.000
    PH                   STD. UNITS      28       6.950       0.269      6.500       6.725       6.900       7.100       7.700
    CHLORIDE             MG/L            28      38.393       1.548     33.000      38.000      39.000      39.000      41.000
    SULFATE              MG/L            27      11.259       3.426      4.000       9.000      12.000      13.000      18.000
    IRON                 MG/L            28       2.644       4.376      0.000       0.267       0.590       2.550      16.000
    MANGANESE            MG/L            28       1.162       0.870      0.020       0.567       1.000       1.475       3.300
    TOTAL NITROGEN       MG/L            28       1.210       0.429      0.590       0.962       1.090       1.295       2.600
    TOTAL KJELDAHL N     MG/L            28       0.914       0.539      0.260       0.525       0.775       1.175       2.600
    ORGANIC N            MG/L            28       0.432       0.383      0.000       0.183       0.335       0.472       1.490
    AMMONIA-N            MG/L            28       0.482       0.589      0.040       0.162       0.280       0.540       2.600
    NITRATE-N            MG/L            28       0.296       0.188      0.000       0.100       0.300       0.400       0.700
    INORGANIC N          MG/L            28       0.779       0.516      0.140       0.522       0.690       0.810       2.600
    TOTAL P              MG/L            28       0.137       0.143      0.010       0.040       0.075       0.235       0.460
    TOTAL DISSOLVED P    MG/L            23       0.068       0.094      0.000       0.010       0.030       0.080       0.340
    SILICA               MG/L            27       4.007       2.086      0.200       2.600       3.600       4.600      10.000
    APPARENT COLOR       PT-CO UNITS     25      29.000      28.976      0.000      10.000      20.000      32.500     100.000
    TOTAL SOLIDS         MG/L            28     141.857      24.318     80.000     128.000     141.000     153.500     212.000
    SUSP.SOLIDS          MG/L            28       2.500       2.046      0.000       1.000       2.000       3.375       7.500

------------------------------- STATION CODE=Q02 LAKE, 300 FT NO. RT.9   DEPTH INTERVAL=SURFACE ----------------------------------

    VARIAB                                N        MEAN         STD        MIN         P25      MEDIAN         P75         MAX

    DISSOLVED OXYGEN     MG/L            46       9.589       1.310      7.100       8.500       9.400      10.500      12.000
    TEMPERATURE          DEG. C          86      15.715       5.826      6.000      10.500      16.500      20.500      26.500
    CHLOROPHYLL-A        MG/M3           13       4.967       1.719      2.300       3.735       4.570       6.640       7.890
    TOTAL ALGAE          CELLS/ML        14    2245.992    2989.051    309.100     456.625     899.200    2592.224    9160.598
    BLUE GREEN ALGAE     CELLS/ML        14     244.871     230.517      0.000      56.200     154.550     372.325     786.800
    DIATOMS              CELLS/ML        14    1834.528    3095.073      0.000      28.100     323.150    2205.849    9048.199
    FLAGELLATES          CELLS/ML        14     126.450     106.717      0.000      49.175     112.400     175.625     421.500
    GREEN ALGAE          CELLS/ML        14      40.143      45.060      0.000       0.000      28.100      63.225     140.500
    CONDUCTIVITY         UHOS/CM         24     194.167      16.659    130.000     190.000     200.000     200.000     220.000
    ALKALINITY           MG/L            24      20.833       2.014     18.000      19.000      20.500      22.000      25.000
    HARDNESS             MG/L            24      42.250       2.048     38.000      41.000      42.000      44.000      45.000
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                                       DATA SUMMARY BY STATION AND DEPTH
------------------------------ STATION CODE=Q02 LAKE, 300 FT NO. RT.9   DEPTH INTERVAL=SURFACE -----------------------------------
   VARIAB                                  N       MEAN        STD       MIN        P25     MEDIAN        P75        MAX

   PH                   STD. UNITS        24      7.279      0.169     6.900      7.125      7.300      7.400      7.500
   CHLORIDE             MG/L              24     36.917      2.669    28.000     36.000     37.000     39.000     40.000
   SULFATE              MG/L              23     12.304      3.225     3.000     11.000     13.000     14.000     16.000
   IRON                 MG/L              24      0.067      0.042     0.000      0.032      0.065      0.100      0.130
   MANGANESE            MG/L              24      0.036      0.027     0.000      0.020      0.030      0.050      0.100
   TOTAL NITROGEN       MG/L              24      0.775      0.331     0.330      0.512      0.765      0.902      1.600
   TOTAL KJELDAHL N     MG/L              24      0.545      0.315     0.090      0.292      0.510      0.585      1.500
   ORGANIC N            MG/L              24      0.495      0.284     0.020      0.280      0.465      0.540      1.300
   AMMONIA-N            MG/L              24      0.050      0.057     0.010      0.020      0.030      0.060      0.240
   NITRATE-N            MG/L              24      0.229      0.146     0.000      0.100      0.200      0.375      0.500
   INORGANIC N          MG/L              24      0.280      0.144     0.010      0.165      0.290      0.390      0.540
   TOTAL P              MG/L              24      0.075      0.093     0.010      0.030      0.035      0.077      0.380
   TOTAL DISSOLVED P    MG/L              17      0.025      0.015     0.000      0.010      0.030      0.040      0.050
   SILICA               MG/L              23      0.861      0.975     0.000      0.000      0.800      1.400      2.900
   APPARENT COLOR       PT-CO UNITS       22     16.364      8.616     5.000      8.750     17.500     21.250     30.000
   SECCHI DEPTH         FT                14      8.071      2.490     5.000      5.825      7.550     10.300     12.500
   TOTAL SOLIDS         MG/L              24    155.917     50.056    56.000    124.000    145.000    199.000    258.000
   SUSP.SOLIDS          MG/L              24      2.000      1.407     0.000      1.000      1.750      3.000      6.000
   TOTAL COLIFORMS      COUNTS/100 ML     15    189.333    189.340    20.000     50.000     70.000    320.000    600.000
   FECAL COLIFORMS      COUNTS/100 ML     15     26.667     27.102     5.000      5.000     20.000     50.000     80.000
   FECAL STREP          COUNTS/100 ML     15      8.667      9.537     5.000      5.000      5.000      5.000     40.000

------------------------------ STATION CODE=Q02 LAKE, 300 FT NO. RT.9   DEPTH INTERVAL=BOTTOM ------------------------------------
   VARIAB                                  N       MEAN        STD       MIN        P25     MEDIAN        P75        MAX

   DISSOLVED OXYGEN     MG/L              58      5.917      3.761     0.000      1.875      7.000      9.125     11.700
   TEMPERATURE          DEG. C           102      7.711      1.228     5.500      7.000      7.500      8.000     13.000
   CONDUCTIVITY         UHOS/CM           30    209.000      8.030   190.000    200.000    210.000    210.000    230.000
   ALKALINITY           MG/L              30     24.567      6.123    18.000     20.750     23.000     27.250     51.000
   HARDNESS             MG/L              30     44.067      2.778    41.000     42.000     44.000     45.000     54.000
   PH                   STD. UNITS        30      7.097      0.227     6.700      6.900      7.050      7.300      7.500
   CHLORIDE             MG/L              30     38.267      3.140    24.000     38.000     39.000     39.250     44.000
   SULFATE              MG/L              29     11.483      2.459     5.000     10.000     12.000     13.000     15.000
   IRON                 MG/L              30      0.762      2.326     0.000      0.082      0.370      0.567     13.000
   MANGANESE            MG/L              30      0.661      0.543     0.010      0.182      0.655      0.960      2.600
   TOTAL NITROGEN       MG/L              30      1.015      0.270     0.410      0.855      0.955      1.147      1.700
   TOTAL KJELDAHL N     MG/L              30      0.645      0.325     0.270      0.445      0.530      0.905      1.600
   ORGANIC N            MG/L              30      0.396      0.342    -0.530      0.217      0.320      0.492      1.410
   AMMONIA-N            MG/L              30      0.249      0.239     0.030      0.115      0.195      0.320      1.200
   NITRATE-N            MG/L              30      0.370      0.173     0.000      0.300      0.400      0.500      0.600
   INORGANIC N          MG/L              30      0.619      0.236     0.030      0.515      0.630      0.692      1.300
   TOTAL P              MG/L              30      0.074      0.082     0.020      0.030      0.040      0.082      0.370
   TOTAL DISSOLVED P    MG/L              24      0.028      0.027     0.010      0.010      0.020      0.037      0.140
   SILICA               MG/L              28      3.375      1.405     1.400      2.525      3.000      4.300      8.200
   APPARENT COLOR       PT-CO UNITS       26     19.231      9.132     5.000     13.750     17.500     25.000     35.000
   TOTAL SOLIDS         MG/L              30    137.400     28.202    54.000    128.000    138.000    148.500    210.000
   SUSP.SOLIDS          MG/L              30      2.233      2.075     0.000      1.000      2.000      3.000     11.000
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                              DATA SUMMARY BY STATION AND DEPTH

-------------------------------- STATION CODE=Q03 LAKE, 300 FT SO. RT.9   DEPTH INTERVAL=SURFACE ----------------------------------

 VARIAB                                   N       MEAN         STD         MIN         P25      MEDIAN         P75          MAX

 DISSOLVED OXYGEN     MG/L               45      9.482       1.481       6.800       8.650       9.000      10.900       12.200
 TEMPERATURE          DEG. C             86     15.657       5.870       6.000      10.500      16.500      20.625       27.500
 CHLOROPHYLL-A        MG/M3              13      5.557       2.412       2.910       3.740       4.980       7.470       10.380
 TOTAL ALGAE          CELLS/ML           14   2588.257    4082.791     281.000     519.850     702.500    2592.225    12575.398
 BLUE GREEN ALGAE     CELLS/ML           14    323.150     440.283       0.000      42.150     210.750     365.300     1573.600
 DIATOMS              CELLS/ML           14   2075.385    4153.094       0.000       0.000     323.150    1292.600    12448.297
 FLAGELLATES          CELLS/ML           14    128.457      89.347      28.100      28.100     154.550     168.600      309.100
 GREEN ALGAE          CELLS/ML           14     74.264     111.099       0.000       0.000       0.000     119.425      309.100
 CONDUCTIVITY         UHOS/CM            25    209.000      24.917     190.000     200.000     200.000     212.500      320.000
 ALKALINITY           MG/L               25     21.480       1.873      20.000      20.000      21.000      22.000       28.000
 HARDNESS             MG/L               25     42.680       1.909      39.000      42.000      42.000      44.000       47.000
 PH                   STD. UNITS         25      7.360       0.200       7.100       7.200       7.400       7.500        8.000
 CHLORIDE             MG/L               25     39.520       2.434      35.000      38.000      39.000      42.000       44.000
 SULFATE              MG/L               23     12.696       2.324       6.000      12.000      13.000      14.000       16.000
 IRON                 MG/L               25      0.113       0.242       0.000       0.020       0.050       0.090        1.200
 MANGANESE            MG/L               25      0.043       0.047       0.010       0.020       0.030       0.045        0.230
 TOTAL NITROGEN       MG/L               25      0.781       0.326       0.300       0.510       0.720       0.970        1.600
 TOTAL KJELDAHL N     MG/L               25      0.545       0.245       0.230       0.395       0.490       0.650        1.200
 ORGANIC N            MG/L               25      0.460       0.232       0.020       0.320       0.400       0.600        1.000
 AMMONIA-N            MG/L               25      0.085       0.121       0.000       0.020       0.040       0.100        0.520
 NITRATE-N            MG/L               25      0.236       0.173       0.000       0.100       0.200       0.400        0.600
 INORGANIC N          MG/L               25      0.321       0.241       0.000       0.125       0.320       0.445        1.120
 TOTAL P              MG/L               25      0.079       0.100       0.020       0.030       0.030       0.085        0.390
 TOTAL DISSOLVED P    MG/L               18      0.021       0.011       0.010       0.010       0.020       0.030        0.040
 SILICA               MG/L               23      1.991       4.114       0.000       0.000       1.000       2.200       20.000
 APPARENT COLOR       PT-CO UNITS        21     16.667      10.288       0.000      10.000      15.000      25.000       40.000
 SECCHI DEPTH         FT                 15      7.980       2.778       4.600       5.300       7.900       9.200       13.800
 TOTAL SOLIDS         MG/L               25    154.720      36.083      98.000     132.000     144.000     192.000      218.000
 SUSP.SOLIDS          MG/L               25      2.000       1.051       0.000       1.250       2.000       2.750        3.500
 TOTAL COLIFORMS      COUNTS/100 ML      14     92.143      95.368      20.000      27.500      60.000     140.000      350.000
 FECAL COLIFORMS      COUNTS/100 ML      14     15.000      14.076       5.000       5.000      10.000      22.500       50.000
 FECAL STREP          COUNTS/100 ML      14      8.929      11.958       5.000       5.000       5.000       6.250       50.000

-------------------------------- STATION CODE=Q03 LAKE, 300 FT SO. RT.9   DEPTH INTERVAL=BOTTOM ----------------------------------

 VARIAB                                   N       MEAN         STD         MIN         P25      MEDIAN         P75          MAX

 DISSOLVED OXYGEN     MG/L               86      4.029       3.898       0.000       0.175       3.250       7.300       13.900
 TEMPERATURE          DEG. C            157      7.532       1.568       5.000       6.500       7.000       8.500       14.500
 CONDUCTIVITY         UHOS/CM            29    231.724      17.180     210.000     220.000     230.000     245.000      265.000
 ALKALINITY           MG/L               29     34.103      12.315      21.000      26.000      28.000      37.000       64.000
 HARDNESS             MG/L               29     47.000       3.901      40.000      44.500      47.000      50.000       56.000
 PH                   STD. UNITS         29      7.138       0.277       6.600       6.950       7.100       7.400        7.600
 CHLORIDE             MG/L               29     42.414       1.900      38.000      41.500      43.000      43.000       47.000
 SULFATE              MG/L               28     12.000       5.256       3.000       9.500      12.000      14.000       26.000
 IRON                 MG/L               29      3.443       4.870       0.000       0.330       0.550       5.950       14.000
 MANGANESE            MG/L               29      1.615       1.277       0.030       0.480       1.300       2.950        4.000
 TOTAL NITROGEN       MG/L               29      1.571       0.876       0.580       0.975       1.200       2.100        4.000
 TOTAL KJELDAHL N     MG/L               29      1.393       0.947       0.380       0.765       0.960       2.000        3.900
 ORGANIC N            MG/L               29      0.345       0.396      -0.100       0.100       0.230       0.525        1.680
 AMMONIA-N            MG/L               29      1.048       1.073       0.090       0.330       0.610       1.500        3.700
 NITRATE-N            MG/L               29      0.178       0.161       0.000       0.000       0.100       0.350        0.500
 INORGANIC N          MG/L               29      1.226       0.991       0.090       0.625       0.810       1.600        3.800
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DATA SUMMARY BY STATION AND DEPTH

STATION CODE=Q03 LAKE, 300 FT SO. RT.9 DEPTH INTERVAL=BOTTOM

VARIAB		N	MEAN	STD	MIN	P25	MEDIAN	P75	MAX
TOTAL P	MG/L	29	0.228	0.274	0.030	0.045	0.080	0.295	0.910
TOTAL DISSOLVED P	MG/L	24	0.128	0.153	0.010	0.032	0.050	0.195	0.550
SILICA	MG/L	28	4.157	2.523	1.400	2.000	3.600	5.350	11.000
APPARENT COLOR	PT-CO UNITS	26	39.808	30.773	5.000	13.750	30.000	60.000	100.000
TOTAL SOLIDS	MG/L	29	156.759	29.907	60.000	142.000	152.000	177.000	224.000
SUSP.SOLIDS	MG/L	29	2.297	1.633	0.000	1.000	2.000	3.250	6.000

STATION CODE=Q04 LAKE, 1000 FT NO.BRIDLE PATH STM.DR DEPTH INTERVAL=SURFACE

VARIAB		N	MEAN	STD	MIN	P25	MEDIAN	P75	MAX
DISSOLVED OXYGEN	MG/L	45	9.240	1.875	1.000	8.250	9.000	10.600	12.100
TEMPERATURE	DEG. C	85	15.886	5.770	6.500	10.500	16.500	20.500	28.000
CHLOROPHYLL-A	MG/M3	13	5.838	2.189	2.490	3.945	6.640	7.680	9.050
TOTAL ALGAE	CELLS/ML	14	2745.771	3206.781	365.300	569.025	1573.600	3315.800	11155.699
BLUE GREEN ALGAE	CELLS/ML	14	303.078	499.295	0.000	70.250	98.350	316.125	1854.600
DIATOMS	CELLS/ML	14	2077.393	3132.972	0.000	84.300	927.300	2472.800	10453.199
FLAGELLATES	CELLS/ML	14	266.950	282.885	0.000	84.300	112.400	484.725	814.900
GREEN ALGAE	CELLS/ML	14	98.350	71.216	0.000	28.100	98.350	168.600	196.700
CONDUCTIVITY	UHOS/CM	24	210.000	11.325	200.000	200.000	210.000	215.000	240.000
ALKALINITY	MG/L	24	22.250	2.132	19.000	21.000	22.000	23.000	28.000
HARDNESS	MG/L	24	43.208	2.553	39.000	42.000	44.000	44.750	48.000
PH	STD. UNITS	24	7.371	0.249	6.900	7.200	7.400	7.575	7.800
CHLORIDE	MG/L	24	40.417	3.063	36.000	38.000	39.500	42.750	49.000
SULFATE	MG/L	22	12.682	2.370	6.000	11.750	13.000	14.250	15.000
IRON	MG/L	24	0.065	0.071	0.000	0.012	0.050	0.090	0.300
MANGANESE	MG/L	24	0.053	0.055	0.000	0.020	0.045	0.060	0.240
TOTAL NITROGEN	MG/L	24	0.700	0.351	0.330	0.417	0.640	0.855	1.600
TOTAL KJELDAHL N	MG/L	24	0.542	0.277	0.310	0.352	0.445	0.740	1.500
ORGANIC N	MG/L	24	0.493	0.239	0.280	0.325	0.400	0.637	1.310
AMMONIA-N	MG/L	24	0.049	0.056	0.000	0.012	0.030	0.072	0.200
NITRATE-N	MG/L	24	0.158	0.156	0.000	0.000	0.100	0.300	0.400
INORGANIC N	MG/L	24	0.207	0.183	0.000	0.030	0.160	0.372	0.530
TOTAL P	MG/L	24	0.083	0.094	0.010	0.022	0.050	0.077	0.340
TOTAL DISSOLVED P	MG/L	18	0.029	0.018	0.010	0.010	0.020	0.042	0.070
SILICA	MG/L	23	1.170	0.995	0.000	0.000	1.300	1.800	3.400
APPARENT COLOR	PT-CO UNITS	21	16.976	14.187	0.000	5.000	15.000	27.500	50.000
SECCHI DEPTH	FT	15	8.807	3.497	4.600	5.900	8.500	11.900	15.600
TOTAL SOLIDS	MG/L	24	162.250	34.335	104.000	132.000	160.000	198.000	214.000
SUSP.SOLIDS	MG/L	24	1.979	1.441	0.000	1.000	2.000	2.875	6.000
TOTAL COLIFORMS	COUNTS/100 ML	15	20.000	20.702	10.000	10.000	10.000	20.000	90.000
FECAL COLIFORMS	COUNTS/100 ML	15	5.667	1.759	5.000	5.000	5.000	5.000	10.000
FECAL STREP	COUNTS/100 ML	15	5.667	1.759	5.000	5.000	5.000	5.000	10.000

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                                 DATA SUMMARY BY STATION AND DEPTH
------------------------ STATION CODE=Q04 LAKE, 1000 FT NO.BRIDLE PATH STM.DR   DEPTH INTERVAL=BOTTOM --------------------------
   VARIAB                              N       MEAN        STD         MIN         P25      MEDIAN         P75         MAX

   DISSOLVED OXYGEN    MG/L           49      3.502      4.022       0.000       0.000       1.300       7.050      11.900
   TEMPERATURE         DEG. C         72      8.056      1.644       5.500       7.000       7.500       9.000      15.500
   CONDUCTIVITY        UHOS/CM        20    237.250     18.742     210.000     220.000     240.000     250.000     270.000
   ALKALINITY          MG/L           20     37.800     12.094      21.000      24.500      38.500      47.750      59.000
   HARDNESS            MG/L           20     46.200      3.636      40.000      44.000      45.000      48.000      54.000
   PH                  STD. UNITS     20      7.090      0.249       6.700       6.825       7.100       7.275       7.600
   CHLORIDE            MG/L           20     43.000      2.616      37.000      41.000      44.000      45.000      46.000
   SULFATE             MG/L           19      9.842      4.549       2.000       7.000      10.000      14.000      18.000
   IRON                MG/L           20      2.741      2.804       0.000       0.137       1.050       5.900       7.100
   MANGANESE           MG/L           20      2.014      1.425       0.020'      0.430       2.300       3.075       4.500
   TOTAL NITROGEN      MG/L           20      2.210      1.898       0.730       1.192       1.600       2.675       9.500
   TOTAL KJELDAHL N    MG/L           20      1.645      0.869       0.540       0.895       1.300       2.475       3.300
   ORGANIC N           MG/L           20      0.353      0.314       0.000       0.100       0.300       0.555       1.000
   AMMONIA-N           MG/L           20      1.291      1.019       0.070       0.320       0.955       2.400       3.000
   NITRATE-N           MG/L           20      0.565      1.757       0.000       0.000       0.100       0.300       8.000
   INORGANIC N         MG/L           20      1.856      1.950       0.400       0.580       1.355       2.575       9.100
   TOTAL P             MG/L           20      0.253      0.228       0.020       0.060       0.170       0.417       0.760
   TOTAL DISSOLVED P   MG/L           14      0.201      0.131       0.030       0.057       0.205       0.305       0.450
   SILICA              MG/L           18      4.917      2.504       1.200       2.725       5.700       6.425       9.500
   APPARENT COLOR      PT-CO UNITS    16     49.781     32.890       1.500      20.000      42.500      77.500     100.000
   TOTAL SOLIDS        MG/L           20    147.890     37.225      17.800     138.500     145.000     169.500     212.000
   SUSP.SOLIDS         MG/L           20      3.650      2.857       0.000       1.500       2.500       5.625       9.000

-------------------------------- STATION CODE=Q05 LAKE @ I-290 BRIDGE   DEPTH INTERVAL=SURFACE ---------------------------------
   VARIAB                              N       MEAN        STD         MIN         P25      MEDIAN         P75         MAX

   DISSOLVED OXYGEN    MG/L           15      9.247      1.599       7.000       8.100       8.800      10.600      12.000
   TEMPERATURE         DEG. C         15     17.760      6.981       6.100      10.500      19.000      24.000      29.000
   CONDUCTIVITY        UHOS/CM        15    197.333     10.328     180.000     190.000     200.000     210.000     210.000
   ALKALINITY          MG/L           15     21.467      3.114      16.000      19.000      20.000      23.000      27.000
   HARDNESS            MG/L           15     40.820      5.908      21.300      39.000      42.000      44.000      48.000
   PH                  STD. UNITS     15      7.253      0.223       6.900       7.000       7.300       7.500       7.500
   CHLORIDE            MG/L           15     36.467      1.506      34.000      35.000      37.000      38.000      39.000
   SULFATE             MG/L           14     11.857      2.214       5.000      11.750      12.000      13.000      15.000
   IRON                MG/L           15      0.169      0.374       0.000       0.030       0.050       0.120       1.500
   MANGANESE           MG/L           15      0.053      0.065       0.000       0.010       0.030       0.060       0.220
   TOTAL NITROGEN      MG/L           15      0.789      0.433       0.330       0.480       0.700       0.870       1.900
   TOTAL KJELDAHL N    MG/L           15      0.602      0.387       0.280       0.360       0.490       0.650       1.800
   ORGANIC N           MG/L           15      0.512      0.413      -0.390       0.350       0.460       0.580       1.570
   AMMONIA-N           MG/L           15      0.090      0.178       0.010       0.010       0.030       0.080       0.700
   NITRATE-N           MG/L           15      0.187      0.151       0.000       0.000       0.200       0.300       0.400
   INORGANIC N         MG/L           15      0.277      0.257       0.010       0.030       0.270       0.420       1.000
   TOTAL P             MG/L           14      0.072      0.089       0.020       0.037       0.050       0.060       0.370
   TOTAL DISSOLVED P   MG/L           10      0.034      0.020       0.010       0.025       0.030       0.040       0.080
   SILICA              MG/L           14      1.264      1.135       0.000       0.075       1.350       2.200       3.600
   APPARENT COLOR      PT-CO UNITS    13     13.077      8.301       0.000       5.000      15.000      20.000      25.000
   TOTAL SOLIDS        MG/L           15    142.120     48.999      23.800     126.000     134.000     184.000     226.000
   SUSP. SOLIDS        MG/L           15      1.967      1.420       0.000       0.500       2.000       3.000       5.000
   TOTAL COLIFORMS     COUNTS/100 ML  15    106.000    138.966      10.000      20.000      40.000     160.000     500.000
   FECAL COLIFORMS     COUNTS/100 ML  15     19.333     20.948       5.000       5.000      10.000      25.000      80.000
   FECAL STREP         COUNTS/100 ML  15     10.667     14.251       5.000       5.000       5.000      10.000      60.000
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                                   DATA SUMMARY BY STATION AND DEPTH

--------------------------------- STATION CODE=Q06 LAKE @ RT.9 BRIDGE   DEPTH INTERVAL=SURFACE ------------------------------------
   VARIAB
                                     N       MEAN         STD        MIN        P25      MEDIAN        P75        MAX

   DISSOLVED OXYGEN    MG/L          14      9.500       1.393      7.300      8.575      9.200      10.550     12.200
   TEMPERATURE         DEG. C        14     17.000       6.557      5.500     10.375     18.500      22.875     25.000
   CONDUCTIVITY        UHOS/CM       15    198.000      10.142    180.000    190.000    200.000     210.000    210.000
   ALKALINITY          MG/L          15     21.867       3.852     18.000     20.000     21.000      23.000     32.000
   HARDNESS            MG/L          15     44.133       5.303     39.000     42.000     42.000      45.000     61.000
   PH                  STD. UNITS    15      7.247       0.253      6.600      7.100      7.300       7.400      7.600
   CHLORIDE            MG/L          15     37.600       1.454     35.000     37.000     37.000      39.000     40.000
   SULFATE             MG/L          14     12.429       2.138      6.000     11.750     13.000      13.250     15.000
   IRON                MG/L          15      0.095       0.138      0.000      0.020      0.060       0.080      0.530
   MANGANESE           MG/L          15      0.045       0.050      0.000      0.020      0.030       0.050      0.210
   TOTAL NITROGEN      MG/L          15      0.723       0.457      0.220      0.340      0.660       0.940      1.800
   TOTAL KJELDAHL N    MG/L          15      0.570       0.388      0.220      0.330      0.460       0.840      1.700
   ORGANIC N           MG/L          15      0.516       0.306      0.210      0.320      0.390       0.760      1.310
   AMMONIA-N           MG/L          15      0.054       0.097      0.000      0.010      0.020       0.070      0.390
   NITRATF-N           MG/L          15      0.153       0.155      0.000      0.000      0.100       0.300      0.400
   INORGANIC N         MG/L          15      0.207       0.187      0.000      0.010      0.180       0.420      0.490
   TOTAL P             MG/L          15      0.069       0.099      0.010      0.020      0.050       0.060      0.410
   TOTAL DISSOLVED P   MG/L          11      0.023       0.012      0.010      0.010      0.020       0.030      0.050
   SILICA              MG/L          14      1.164       1.176      0.000      0.150      0.850       2.025      3.900
   APPARENT COLOR      PT-CO UNITS   13     15.000      11.902      0.000      5.000     15.000      25.000     35.000
   TOTAL SOLIDS        MG/L          15    141.233      49.566     18.500    114.000    130.000     184.000    222.000
   SUSP.SOLIDS         MG/L          15      1.833       1.611      0.000      0.500      1.500       2.500      5.500
   TOTAL COLIFORMS     COUNTS/100 ML 15    192.333     173.811      5.000     60.000    120.000     320.000    600.000
   FECAL COLIFORMS     COUNTS/100 ML 15     53.333      68.051      5.000     10.000     25.000      60.000    230.000
   FECAL STREP         COUNTS/100 ML 15      9.667       7.669      5.000      5.000      5.000      10.000     30.000

--------------------------------- STATION CODE=Q08 FITZGERALD BROOK   DEPTH INTERVAL=SURFACE ------------------------------------
VARIAB
                                     N       MEAN         STD        MIN        P25      MEDIAN        P75          MAX

DISSOLVED OXYGEN    MG/L             14     10.336       1.784      7.500      8.800     10.450      11.425       14.000
TEMPERATURE         DEG. C           14     11.950       5.774      0.000      6.750     13.000      17.250       19.000
CONDUCTIVITY        UHOS/CM          14    301.428      33.708    250.000    277.500    290.000     340.000      360.000
ALKALINITY          MG/L             14     26.286       2.673     19.000     25.000     26.500      28.000       30.000
HARDNESS            MG/L             14     72.143       8.113     59.000     64.000     72.500      79.250       86.000
PH                  STD. UNITS       14      7.421       0.309      6.900      7.175      7.450       7.625        7.900
CHLORIDE            MG/L             14     51.429       5.761     43.000     47.000     51.000      57.500       60.000
SULFATE             MG/L             13     32.000      16.985     16.000     26.500     29.000      30.000       87.000
IRON                MG/L             14      0.079       0.067      0.000      0.020      0.070       0.117        0.210
MANGANESE           MG/L             14      0.039       0.057      0.000      0.010      0.020       0.042        0.220
TOTAL NITROGEN      MG/L             14      1.850       0.253      1.430      1.675      1.815       2.022        2.280
TOTAL KJELDAHL N    MG/L             14      0.557       0.243      0.180      0.375      0.500       0.805        0.980
ORGANIC N           MG/L             14      0.486       0.258      0.030      0.320      0.490       0.592        0.960
AMMONIA-N           MG/L             14      0.071       0.120      0.000      0.010      0.025       0.055        0.400
NITRATE-N           MG/L             14      1.293       0.202      0.900      1.175      1.300       1.500        1.600
INORGANIC N         MG/L             14      1.364       0.262      0.940      1.185      1.320       1.530        2.000
TOTAL P             MG/L             14      0.082       0.044      0.030      0.047      0.080       0.090        0.180
TOTAL DISSOLVED P   MG/L              9      0.060       0.020      0.040      0.040      0.060       0.080        0.090
SILICA              MG/L             12     13.000       2.763     10.000     11.000     12.500      14.000       20.000
APPARENT COLOR      PT-CO UNITS      11      5.455       6.876      0.000      0.000      5.000      10.000       20.000
TOTAL SOLIDS        MG/L             14    194.186      54.773     18.600    187.500    203.000     224.000      244.000
SUSP.SOLIDS         MG/L             14      0.786       1.267      0.000      0.000      0.250       1.500        4.500
TOTAL COLIFORMS     COUNTS/100 ML    14   8305.000   12156.492    370.000   1275.000   2750.000   13500.000    42000.000
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                                      DATA SUMMARY BY STATION AND DEPTH
----------------------------------- STATION CODE=Q08 FITZGERALD BROOK   DEPTH INTERVAL=SURFACE --------------------------------------

                VARIAB                          N       MEAN          STD         MIN         P25       MEDIAN        P75         MAX

        FECAL COLIFORMS      COUNTS/100 ML     14     951.786     1116.815      15.000     177.500     550.000    1250.000    4000.000
        FECAL STREP          COUNTS/100 ML     13     226.923      296.574      10.000      35.000      90.000     300.000     900.000

----------------------------------- STATION CODE=Q09 COALMINE BROOK   DEPTH INTERVAL=SURFACE --------------------------------------

    VARIAB                                    N        MEAN          STD         MIN         P25       MEDIAN         P75          MAX

    DISSOLVED OXYGEN     MG/L                14       10.614        2.343       8.300       8.500      10.500      11.900       14.900
    TEMPERATURE          DEG. C              14       12.429        6.696      -0.500       5.375      13.500      17.500       22.000
    CONDUCTIVITY         UHOS/CM             14      328.571       29.314     290.000     307.500     330.000     340.000      400.000
    ALKALINITY           MG/L                14       36.857        7.715      22.000      32.750      38.000      42.750       48.000
    HARDNESS             MG/L                14       83.643       11.460      70.000      75.500      81.000      88.250      110.000
    PH                   STD. UNITS          14        7.586        0.301       7.100       7.375       7.500       7.725        8.200
    CHLORIDE             MG/L                14       61.786       15.328      51.000      52.000      58.500      62.500      109.000
    SULFATE              MG/L                13       24.538        5.010      10.000      22.500      26.000      27.000       29.000
    IRON                 MG/L                14        0.089        0.106       0.000       0.027       0.050       0.127        0.380
    MANGANESE            MG/L                14        0.028        0.026       0.000       0.010       0.020       0.037        0.080
    TOTAL NITROGEN       MG/L                14        1.282        0.288       0.880       1.025       1.335       1.437        1.890
    TOTAL KJELDAHL N     MG/L                14        0.525        0.214       0.300       0.347       0.435       0.752        0.950
    ORGANIC N            MG/L                14        0.474        0.211       0.200       0.307       0.415       0.610        0.930
    AMMONIA-N            MG/L                14        0.051        0.064       0.000       0.010       0.035       0.065        0.250
    NITRATE-N            MG/L                14        0.757        0.238       0.300       0.600       0.700       0.950        1.100
    INORGANIC N          MG/L                14        0.808        0.286       0.310       0.610       0.730       1.000        1.350
    TOTAL P              MG/L                14        0.081        0.035       0.040       0.047       0.080       0.100        0.170
    TOTAL DISSOLVED P    MG/L                 9        0.064        0.024       0.040       0.045       0.050       0.090        0.100
    SILICA               MG/L                12        9.700        2.017       7.500       8.000       9.600      10.000       14.000
    APPARENT COLOR       PT-CO UNITS         10        9.050       13.463       0.000       0.000       2.750      13.750       40.000
    TOTAL SOLIDS         MG/L                14      223.000       19.996     192.000     208.500     221.000     234.500      266.000
    SUSP. SOLIDS         MG/L                14        1.964        3.177       0.000       0.000       0.250       3.625        8.500
    TOTAL COLIFORMS      COUNTS/100 ML       14    14732.855    17711.887      10.000     862.500    6300.000   35000.000    51000.000
    FECAL COLIFORMS      COUNTS/100 ML       14     1305.000     1529.522       5.000     145.000     562.500    3050.000     4000.000
    FECAL STREP          COUNTS/100 ML       13      278.077      372.075       5.000      30.000      60.000     465.000     1300.000

----------------------------------- STATION CODE=Q10 POOR FARM BROOK   DEPTH INTERVAL=SURFACE --------------------------------------

      VARIAB                                    N        MEAN          STD         MIN         P25       MEDIAN        P75          MAX

      DISSOLVED OXYGEN     MG/L                13        9.300        2.740       5.000       7.300       9.200      11.800       13.000
      TEMPERATURE          DEG. C              13       13.315        8.824      -0.500       5.350      16.000      20.750       27.000
      CONDUCTIVITY         UHOS/CM             13      246.154       32.026     180.000     235.000     240.000     265.000      320.000
      ALKALINITY           MG/L                13       36.692        9.304      26.000      29.500      33.000      42.500       58.000
      HARDNESS             MG/L                13       64.615       11.310      43.000      59.000      63.000      70.000       85.000
      PH                   STD. UNITS          13        7.446        0.369       6.900       7.150       7.500       7.650        8.200
      CHLORIDE             MG/L                13       38.077        9.887      20.000      31.500      39.000      42.000       62.000
      SULFATE              MG/L                12       17.583        5.435       9.000      16.000      18.000      18.000       31.000
      IRON                 MG/L                13        0.687        0.421       0.080       0.365       0.630       1.050        1.400
      MANGANESE            MG/L -              13        0.205        0.254       0.020       0.075       0.100       0.180        0.800
      TOTAL NITROGEN       MG/L                13        1.152        0.249       0.790       0.960       1.140       1.345        1.550
      TOTAL KJELDAHL N     MG/L                13        0.686        0.237       0.390       0.475       0.610       0.875        1.200
      ORGANIC N            MG/L                13        0.612        0.224       0.370       0.430       0.540       0.750        1.160
      AMMONIA-N            MG/L                13        0.074        0.060       0.020       0.040       0.050       0.100        0.230
      NITRATE-N            MG/L                13        0.465        0.294       0.000       0.300       0.400       0.700        1.000
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                                DATA SUMMARY BY STATION AND DEPTH

------------------------------- STATION CODE=Q10 POOR FARM BROOK   DEPTH INTERVAL=SURFACE ---------------------------------

 VARIAB                                N        MEAN         STD        MIN        P25     MEDIAN        P75          MAX

 INORGANIC N         MG/L             13       0.539       0.290      0.040      0.385      0.440      0.785        1.080
 TOTAL P             MG/L             13       0.063       0.025      0.030      0.045      0.050      0.085        0.110
 TOTAL DISSOLVED P   MG/L              8       0.041       0.022      0.020      0.030      0.035      0.047        0.090
 SILICA              MG/L             11       6.816       2.732      0.280      5.400      6.800      9.000        9.600
 APPARENT COLOR      PT-CO UNITS      10      25.500      12.572      5.000     17.500     25.000     36.250       45.000
 TOTAL SOLIDS        MG/L             13     185.000      56.312    138.000    159.000    166.000    196.000      361.000
 SUSP.SOLIDS         MG/L             13       3.808       4.922      0.000      0.500      1.500      6.000       15.000
 TOTAL COLIFORMS     COUNTS/100 ML    13    2174.615    5964.074     60.000    270.000    630.000    875.000    22000.000
 FECAL COLIFORMS     COUNTS/100 ML    13     163.462     405.737      5.000     17.500     30.000    102.500     1500.000
 FECAL STREP         COUNTS/100 ML    12     117.500     142.789      5.000     10.000     70.000    202.500      480.000

------------------------------- STATION CODE=Q11 NEWTON POND OUTLET   DEPTH INTERVAL=SURFACE -------------------------------

 VARIAB                                N        MEAN         STD        MIN        P25     MEDIAN        P75          MAX

 DISSOLVED OXYGEN    MG/L             15       8.080       3.084      3.000      6.400      7.600     11.100       13.300
 TEMPERATURE         DEG. C           15      14.480       7.749      1.000      8.300     16.000     21.000       25.000
 CONDUCTIVITY        UHOS/CM          15     124.400      20.241     95.000    100.000    130.000    140.000      170.000
 ALKALINITY          MG/L             15      18.200       3.234     12.000     16.000     19.000     20.000       24.000
 HARDNESS            MG/L             15      30.133       3.944     25.000     27.000     30.000     32.000       38.000
 PH                  STD. UNITS       15       7.180       0.166      6.900      7.000      7.200      7.300        7.400
 CHLORIDE            MG/L             15      21.600       9.440     11.000     17.000     22.000     23.000       52.000
 SULFATE             MG/L             14       8.357       2.468      5.000      6.750      8.500     10.000       14.000
 IRON                MG/L             15       0.181       0.135      0.000      0.080      0.130      0.240        0.500
 MANGANESE           MG/L             15       0.037       0.061      0.000      0.000      0.030      0.040        0.250
 TOTAL NITROGEN      MG/L             15       0.655       0.201      0.360      0.490      0.680      0.740        1.040
 TOTAL KJELDAHL N    MG/L             15       0.554       0.205      0.260      0.410      0.550      0.680        1.000
 ORGANIC N           MG/L             15       0.519       0.224      0.170      0.380      0.550      0.680        0.990
 AMMONIA-N           MG/L             15       0.035       0.052      0.000      0.000      0.030      0.040        0.210
 NITRATE-N           MG/L             15       0.101       0.100      0.000      0.000      0.100      0.200        0.300
 INORGANIC N         MG/L             15       0.136       0.112      0.000      0.010      0.150      0.240        0.330
 TOTAL P             MG/L             15       0.039       0.025      0.010      0.020      0.030      0.040        0.110
 TOTAL DISSOLVED P   MG/L             10       0.028       0.015      0.010      0.017      0.025      0.040        0.060
 SILICA              MG/L             13       0.608       0.645      0.000      0.000      0.400      1.150        2.000
 APPARENT COLOR      PT-CO UNITS      12      16.667      11.742      0.000      6.250     17.500     30.000       30.000
 TOTAL SOLIDS        MG/L             15     104.267      35.107     62.000     80.000     94.000    126.000      196.000
 SUSP.SOLIDS         MG/L             15       2.933       7.583      0.000      0.000      1.000      2.000       30.000
 TOTAL COLIFORMS     COUNTS/100 ML    15     427.667    1007.484     10.000     30.000    140.000    250.000     4000.000
 FECAL COLIFORMS     COUNTS/100 ML    15      30.333      32.264      5.000      5.000     15.000     60.000      100.000
 FECAL STREP         COUNTS/100 ML    14      13.571      19.945      5.000      5.000      5.000     16.250       80.000

------------------------------- STATION CODE=Q12 LAKE @ LINCOLN ST.   DEPTH INTERVAL=SURFACE --------------------------------

 VARIAB                                N        MEAN         STD        MIN        P25     MEDIAN        P75          MAX

 DISSOLVED OXYGEN    MG/L             15       7.767       2.945      2.300      5.600      8.700     10.600       12.000
 TEMPERATURE         DEG. C           15      16.380       7.714      0.000     11.100     19.000     21.000       27.000
 CONDUCTIVITY        UHOS/CM          15     151.000      29.350    120.000    130.000    150.000    155.000      210.000
 ALKALINITY          MG/L             15      21.600       4.421     15.000     19.000     21.000     23.000       33.000
 HARDNESS            MG/L             15      35.467       5.693     27.000     32.000     33.000     42.000       44.000
 PH                  STD. UNITS       15       7.200       0.293      6.700      7.000      7.300      7.400        7.700
 CHLORIDE            MG/L             15      26.667       8.869     19.000     21.000     23.000     36.000       48.000
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DATA SUMMARY BY STATION AND DEPTH

STATION CODE=Q12 LAKE @ LINCOLN ST. DEPTH INTERVAL=SURFACE

VARIAB		N	MEAN	STD	MIN	P25	MEDIAN	P75	MAX
SULFATE	MG/L	14	10.286	2.867	6.000	8.500	10.000	13.000	15.000
IRON	MG/L	15	0.215	0.176	0.000	0.060	0.140	0.320	0.560
MANGANESE	MG/L	15	0.045	0.044	0.000	0.020	0.020	0.080	0.160
TOTAL NITROGEN	MG/L	15	0.801	0.267	0.340	0.680	0.740	0.920	1.500
TOTAL KJELDAHL N	MG/L	15	0.694	0.233	0.340	0.500	0.740	0.760	1.200
ORGANIC N	MG/L	15	0.648	0.241	0.330	0.450	0.670	0.740	1.160
AMMONIA-N	MG/L	15	0.046	0.035	0.010	0.010	0.040	0.070	0.130
NITRATE-N	MG/L	15	0.107	0.158	0.000	0.000	0.000	0.200	0.500
INORGANIC N	MG/L	15	0.153	0.168	0.010	0.020	0.090	0.230	0.560
TOTAL P	MG/L	15	0.056	0.036	0.010	0.030	0.040	0.080	0.150
TOTAL DISSOLVED P	MG/L	11	0.033	0.018	0.010	0.010	0.030	0.040	0.070
SILICA	MG/L	14	1.121	0.932	0.000	0.225	1.000	1.925	2.700
APPARENT COLOR	PT-CO UNITS	13	21.154	16.350	0.000	5.000	25.000	30.000	50.000
TOTAL SOLIDS	MG/L	15	144.000	83.948	32.000	84.000	108.000	202.000	314.000
SUSP. SOLIDS	MG/L	15	2.133	1.737	0.000	1.000	1.500	4.000	5.000
TOTAL COLIFORMS	COUNTS/100 ML	15	284.000	556.094	10.000	30.000	40.000	400.000	2200.000
FECAL COLIFORMS	COUNTS/100 ML	15	53.333	125.138	5.000	5.000	10.000	20.000	480.000
FECAL STREP	COUNTS/100 ML	15	21.000	29.532	5.000	5.000	10.000	30.000	120.000

STATION CODE=Q13 BILLINGS BROOK DEPTH INTERVAL=SURFACE

VARIAB		N	MEAN	STD	MIN	P25	MEDIAN	P75	MAX
DISSOLVED OXYGEN	MG/L	16	7.681	2.703	3.200	5.275	7.450	10.275	11.800
TEMPERATURE	DEG. C	16	13.712	7.251	1.000	7.325	15.500	19.000	24.000
CONDUCTIVITY	UHOS/CM	16	223.750	36.125	160.000	192.500	225.000	250.000	300.000
ALKALINITY	MG/L	16	19.813	4.578	14.000	17.250	19.500	21.000	34.000
HARDNESS	MG/L	16	53.625	17.595	36.000	43.500	49.000	55.500	113.000
PH	STD. UNITS	16	6.906	0.235	6.500	6.725	6.800	7.075	7.400
CHLORIDE	MG/L	16	43.000	9.018	30.000	37.250	40.500	51.750	61.000
SULFATE	MG/L	15	17.133	4.068	8.000	15.000	17.000	20.000	24.000
IRON	MG/L	16	0.671	0.433	0.130	0.245	0.600	1.025	1.600
MANGANESE	MG/L	16	0.088	0.048	0.010	0.047	0.090	0.117	0.200
TOTAL NITROGEN	MG/L	16	1.317	0.461	0.650	1.012	1.215	1.580	2.500
TOTAL KJELDAHL N	MG/L	16	0.711	0.301	0.250	0.415	0.640	0.955	1.700
ORGANIC N	MG/L	16	0.611	0.398	0.180	0.292	0.540	0.865	1.680
AMMONIA-N	MG/L	16	0.100	0.086	0.020	0.052	0.070	0.127	0.370
NITRATE-N	MG/L	16	0.606	0.188	0.400	0.425	0.600	0.775	1.000
INORGANIC N	MG/L	16	0.706	0.173	0.460	0.550	0.695	0.835	1.050
TOTAL P	MG/L	16	0.056	0.036	0.020	0.040	0.050	0.060	0.180
TOTAL DISSOLVED P	MG/L	11	0.025	0.009	0.010	0.020	0.020	0.030	0.040
SILICA	MG/L	14	6.157	2.155	1.200	4.750	6.700	7.600	9.300
APPARENT COLOR	PT-CO UNITS	12	17.500	10.766	0.000	11.250	17.500	25.000	35.000
TOTAL SOLIDS	MG/L	16	145.750	31.991	100.000	113.000	141.000	174.500	206.000
SUSP. SOLIDS	MG/L	16	3.969	3.052	0.000	2.000	3.250	6.125	11.500
TOTAL COLIFORMS	COUNTS/100 ML	16	301.875	250.765	10.000	45.000	290.000	495.000	800.000
FECAL COLIFORMS	COUNTS/100 ML	16	47.500	51.737	5.000	5.000	35.000	92.500	180.000
FECAL STREP	COUNTS/100 ML	15	41.000	59.046	5.000	5.000	10.000	50.000	200.000

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                                        DATA SUMMARY BY STATION AND DEPTH

------------------------------------- STATION CODE=Q15 O HARA BROOK   DEPTH INTERVAL=SURFACE -------------------------------------

VARIAB                                N        MEAN          STD          MIN          P25       MEDIAN          P75          MAX

DISSOLVED OXYGEN    MG/L              9       9.878        1.844        7.800        8.050       10.000       11.650       12.600
TEMPERATURE         DEG. C            9      12.222        6.073        4.000        5.250       12.000       17.750       19.000
CONDUCTIVITY        UHOS/CM           9     268.889       35.158      230.000      235.000      270.000      300.000      320.000
ALKALINITY          MG/L              9      30.000        6.801       18.000       25.500       31.000       34.000       40.000
HARDNESS            MG/L              9      59.889        8.146       48.000       52.500       62.000       66.500       72.000
PH                  STD. UNITS        9       7.278        0.387        6.800        7.000        7.200        7.450        8.100
CHLORIDE            MG/L              9      47.444        8.487       35.000       39.000       47.000       56.000       57.000
SULFATE             MG/L              8      20.375        7.210        8.000       17.000       20.500       24.250       33.000
IRON                MG/L              9       0.139        0.148        0.000        0.035        0.100        0.190        0.490
MANGANESE           MG/L              9       0.042        0.057        0.000        0.005        0.020        0.075        0.170
TOTAL NITROGEN      MG/L              9       1.318        0.479        0.910        1.010        1.170        1.430        2.500
TOTAL KJE'DAHL N    MG/L              9       0.651        0.414        0.350        0.425        0.530        0.700        1.700
ORGANIC N           MG/L              9       0.602        0.424        0.240        0.405        0.440        0.640        1.680
AMMONIA-N           MG/L              9       0.049        0.043        0.000        0.010        0.030        0.095        0.110
NITRATE-N           MG/L              9       0.667        0.194        0.400        0.450        0.800        0.800        0.900
INORGANIC N         MG/L              9       0.716        0.217        0.400        0.490        0.810        0.905        0.990
TOTAL P             MG/L              9       0.074        0.101        0.010        0.030        0.040        0.065        0.340
TOTAL DISSOLVED P   MG/L              6       0.035        0.014        0.020        0.027        0.030        0.045        0.060
SILICA              MG/L              8       8.062        3.015        1.900        6.400        8.600       10.700       11.000
APPARENT COLOR      PT-CO UNITS       6      12.500       14.053        0.000        3.750        5.000       27.500       35.000
TOTAL SOLIDS        MG/L              9     164.222       48.399       48.000      149.000      186.000      195.000      204.000
SUSP.SOLIDS         MG/L              9       2.167        2.704        0.000        0.000        1.000        4.250        7.500
TOTAL COLIFORMS     COUNTS/100 ML     9    8848.887    11228.844       40.000     1200.000     2700.000    19000.000    31000.000
FECAL COLIFORMS     COUNTS/100 ML     9     581.667      739.603        5.000       25.000      250.000     1250.000     2000.000
FECAL STREP         COUNTS/100 ML     9     265.555      334.135        5.000       12.500       50.000      490.000      960.000

------------------------------- STATION CODE=Q16 MEDICAL SCHOOL DRAIN   DEPTH INTERVAL=SURFACE -------------------------------

VARIAB                                N        MEAN          STD          MIN          P25       MEDIAN          P75          MAX

DISSOLVED OXYGEN    MG/L             16      10.000        1.499        8.400        8.825        9.400       11.300       13.300
TEMPERATURE         DEG. C           16      15.387        7.664        1.700        7.000       16.000       23.500       25.000
CONDUCTIVITY        UHOS/CM          16     277.500       73.711      190.000      212.500      260.000      335.000      450.000
ALKALINITY          MG/L             16      24.168        4.370       16.000       20.250       24.500       28.500       31.000
HARDNESS            MG/L             16      63.750       21.186       42.000       45.500       59.000       75.250      120.000
PH                  STD. UNITS       16       7.269        0.224        6.900        7.100        7.300        7.400        7.800
CHLORIDE            MG/L             16      42.939       15.277       20.000       36.250       40.500       47.750       80.000
SULFATE             MG/L             15      30.200       20.868       13.000       14.000       22.000       36.000       92.000
IRON                MG/L             16       0.116        0.118        0.000        0.022        0.080        0.195        0.390
MANGANESE           MG/L             16       0.198        0.212        0.010        0.040        0.115        0.275        0.750
TOTAL NITROGEN      MG/L             16       1.134        0.447        0.630        0.695        1.080        1.402        2.300
TOTAL KJELDAHL N    MG/L             16       0.666        0.343        0.270        0.435        0.550        0.797        1.400
ORGANIC N           MG/L             16       0.612        0.317        0.210        0.397        0.525        0.750        1.310
AMMONIA-N           MG/L             16       0.054        0.047        0.010        0.012        0.040        0.077        0.180
NITRATE-N           MG/L             16       0.469        0.287        0.100        0.225        0.400        0.750        1.000
INORGANIC N         MG/L             16       0.522        0.292        0.110        0.297        0.475        0.767        1.040
TOTAL P             MG/L             16       0.041        0.024        0.000        0.020        0.040        0.050        0.090
TOTAL DISSOLVED P   MG/L             11       0.024        0.016        0.010        0.010        0.020        0.040        0.050
SILICA              MG/L             14       3.071        2.620        0.000        1.025        2.750        4.625        8.000
APPARENT COLOR      PT-CO UNITS      12      16.250       10.262        5.000        6.250       17.500       20.000       40.000
TOTAL SOLIDS        MG/L             16     164.625       71.534       40.000      119.000      173.000      200.500      312.000
SUSP.SOLIDS         MG/L             16       3.594        1.819        0.000        2.250        3.500        5.000        6.500
TOTAL COLIFORMS     COUNTS/100 ML    16     563.125      670.002       60.000      205.000      310.000      675.000     2700.000
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DATA SUMMARY BY STATION AND DEPTH

STATION CODE=Q16 MEDICAL SCHOOL DRAIN DEPTH INTERVAL=SURFACE

VARIAB		N	MEAN	STD	MIN	P25	MEDIAN	P75	MAX
FECAL COLIFORMS	COUNTS/100 ML	16	56.563	72.565	5.000	10.000	15.000	95.000	240.000
FECAL STREP	COUNTS/100 ML	15	107.667	189.132	5.000	10.000	40.000	80.000	650.000

STATION CODE=Q17 TILLY BROOK DEPTH INTERVAL=SURFACE

VARIAB		N	MEAN	STD	MIN	P25	MEDIAN	P75	MAX
DISSOLVED OXYGEN	MG/L	15	9.000	1.560	6.800	7.700	8.800	10.100	11.900
TEMPERATURE	DEG. C	14	16.229	6.473	3.000	11.650	17.500	21.250	24.000
CONDUCTIVITY	UHOS/CM	15	173.000	41.952	125.000	135.000	165.000	210.000	250.000
ALKALINITY	MG/L	15	19.067	7.815	9.000	14.000	16.000	28.000	34.000
HARDNESS	MG/L	15	38.000	10.142	27.000	29.000	35.000	47.000	55.000
PH	STD. UNITS	15	7.093	0.212	6.800	6.900	7.100	7.300	7.400
CHLORIDE	MG/L	15	34.400	18.879	15.000	25.000	27.000	38.000	90.000
SULFATE	MG/L	14	14.929	5.327	9.000	9.750	15.000	17.250	27.000
IRON	MG/L	15	0.265	0.223	0.000	0.090	0.210	0.420	0.770
MANGANESE	MG/L	15	0.045	0.028	0.010	0.030	0.030	0.070	0.110
TOTAL NITROGEN	MG/L	15	1.115	0.345	0.430	0.970	1.090	1.350	1.700
TOTAL KJELDAHL N	MG/L	15	0.789	0.296	0.330	0.570	0.870	0.960	1.500
ORGANIC N	MG/L	15	0.731	0.305	0.240	0.430	0.800	0.910	1.460
AMMONIA-N	MG/L	15	0.057	0.065	0.000	0.020	0.040	0.090	0.260
NITRATE-N	MG/L	15	0.327	0.222	0.100	0.200	0.200	0.400	0.800
INORGANIC N	MG/L	15	0.384	0.233	0.100	0.220	0.250	0.660	0.820
TOTAL P	MG/L	15	0.052	0.029	0.010	0.030	0.040	0.070	0.100
TOTAL DISSOLVED P	MG/L	11	0.031	0.016	0.010	0.020	0.030	0.050	0.050
SILICA	MG/L	14	3.436	2.805	0.100	1.025	2.850	5.000	9.300
APPARENT COLOR	PT-CO UNITS	12	42.917	26.238	10.000	16.250	42.500	67.500	90.000
TOTAL SOLIDS	MG/L	15	114.400	31.597	82.000	94.000	104.000	132.000	180.000
SUSP.SOLIDS	MG/L	15	2.833	1.988	0.000	2.000	2.500	3.000	8.000
TOTAL COLIFORMS	COUNTS/100 ML	14	30879.285	65947.375	40.000	327.500	4400.000	25750.000	240000
FECAL COLIFORMS	COUNTS/100 ML	14	2803.571	5883.676	5.000	10.000	240.000	2000.000	20000.000
FECAL STREP	COUNTS/100 ML	14	202.500	353.263	5.000	5.000	70.000	207.500	1300.000

STATION CODE=Q18 JORDAN POND OUTLET DEPTH INTERVAL=SURFACE

VARIAB		N	MEAN	STD	MIN	P25	MEDIAN	P75	MAX
DISSOLVED OXYGEN	MG/L	4	8.275	1.621	6.700	6.800	8.200	9.825	10.000
TEMPERATURE	DEG. C	4	15.250	4.992	10.000	11.000	14.500	20.250	22.000
CONDUCTIVITY	UHOS/CM	4	155.000	5.774	150.000	150.000	155.000	160.000	160.000
ALKALINITY	MG/L	4	23.250	8.539	18.000	18.250	19.500	32.000	36.000
HARDNESS	MG/L	4	29.750	1.708	28.000	28.250	29.500	31.500	32.000
PH	STD. UNITS	4	7.150	0.129	7.000	7.025	7.150	7.275	7.300
CHLORIDE	MG/L	4	27.000	1.826	25.000	25.250	27.000	28.750	29.000
SULFATE	MG/L	4	11.750	3.304	7.000	8.250	13.000	14.000	14.000
IRON	MG/L	4	0.130	0.057	0.060	0.077	0.130	0.182	0.200
MANGANESE	MG/L	4	0.022	0.013	0.010	0.012	0.020	0.035	0.040
TOTAL NITROGEN	MG/L	4	0.670	0.029	0.640	0.645	0.665	0.700	0.710
TOTAL KJELDAHL N	MG/L	4	0.570	0.054	0.510	0.522	0.565	0.622	0.640
ORGANIC N	MG/L	4	0.497	0.060	0.410	0.435	0.520	0.537	0.540
AMMONIA-N	MG/L	4	0.072	0.034	0.030	0.037	0.080	0.100	0.100
NITRATE-N	MG/L	4	0.100	0.032	0.000	0.025	0.100	0.175	0.200

DATA SUMMARY BY STATION AND DEPTH

STATION CODE=Q18 JORDAN POND OUTLET   DEPTH INTERVAL=SURFACE

VARIAB		N	MEAN	STD	MIN	P25	MEDIAN	P75	MAX
INORGANIC N	MG/L	4	0.172	0.088	0.100	0.107	0.145	0.265	0.300
TOTAL P	MG/L	4	0.035	0.010	0.020	0.025	0.040	0.040	0.040
TOTAL DISSOLVED P	MG/L	1	0.010	.	0.010	0.010	0.010	0.010	0.010
SILICA	MG/L	3	0.100	0.173	0.000	0.000	0.000	0.300	0.300
APPARENT COLOR	PT-CO UNITS	2	10.000	0.000	10.000	10.000	10.000	10.000	10.000
TOTAL SOLIDS	MG/L	4	142.500	39.979	104.000	106.000	144.000	177.500	178.000
SUSP.SOLIDS	MG/L	4	0.875	0.479	0.500	0.500	0.750	1.375	1.500
TOTAL COLIFORMS	COUNTS/100 ML	4	12592.500	18848.383	170.000	177.500	5100.000	32500.000	40000.000
FECAL COLIFORMS	COUNTS/100 ML	4	982.500	1569.424	10.000	12.500	310.000	2625.000	3300.000
FECAL STREP	COUNTS/100 ML	4	185.000	343.535	5.000	5.000	17.500	532.500	700.000

STATION CODE=Q19 BELMONT STREET DRAIN   DEPTH INTERVAL=SURFACE

VARIAB		N	MEAN	STD	MIN	P25	MEDIAN	P75	MAX
DISSOLVED OXYGEN	MG/L	14	8.221	2.003	5.300	6.625	8.550	9.725	11.300
TEMPERATURE	DEG. C	14	15.950	5.248	8.000	10.750	16.500	22.000	23.000
CONDUCTIVITY	UHOS/CM	14	437.857	99.009	250.000	330.000	490.000	505.000	520.000
ALKALINITY	MG/L	14	31.000	9.527	13.000	24.000	29.500	38.500	46.000
HARDNESS	MG/L	14	83.643	20.056	51.000	61.750	90.000	96.000	120.000
PH	STD. UNITS	14	7.214	0.166	6.900	7.100	7.200	7.325	7.500
CHLORIDE	MG/L	14	76.714	30.738	25.000	43.750	90.500	100.000	115.000
SULFATE	MG/L	14	30.571	9.913	9.000	23.000	32.000	39.000	45.000
IRON	MG/L	14	0.724	0.652	0.090	0.257	0.545	0.930	2.400
MANGANESE	MG/L	14	0.529	0.416	0.060	0.165	0.455	0.770	1.300
TOTAL NITROGEN	MG/L	14	3.226	1.205	1.390	2.390	3.075	4.237	5.400
TOTAL KJELDAHL N	MG/L	14	1.462	0.643	0.820	0.990	1.150	2.000	2.950
ORGANIC N	MG/L	14	0.983	0.479	0.280	0.715	0.795	1.232	1.950
AMMONIA-N	MG/L	14	0.479	0.333	0.110	0.235	0.370	0.617	1.300
NITRATE-N	MG/L	14	1.764	0.948	0.500	1.100	1.800	2.175	3.900
INORGANIC N	MG/L	14	2.244	1.014	0.660	1.485	2.260	2.775	4.250
TOTAL P	MG/L	14	0.261	0.189	0.060	0.117	0.230	0.310	0.800
TOTAL DISSOLVED P	MG/L	11	0.105	0.066	0.040	0.050	0.090	0.150	0.240
SILICA	MG/L	13	2.938	2.498	0.900	1.200	1.600	5.300	8.000
APPARENT COLOR	PT-CO UNITS	12	17.917	24.905	0.000	5.000	10.000	15.000	90.000
TOTAL SOLIDS	MG/L	14	292.714	64.606	142.000	245.500	313.000	335.000	368.000
SUSP.SOLIDS	MG/L	14	3.964	2.239	0.000	2.075	3.850	5.875	7.500
TOTAL COLIFORMS	COUNTS/100 ML	14	158000	392404	5000.000	9750.000	29000.000	92250.000	1500000
FECAL COLIFORMS	COUNTS/100 ML	14	11464.285	23982.445	600.000	2625.000	3750.000	8125.000	93000.000
FECAL STREP	COUNTS/100 ML	13	1094.615	1306.079	20.000	250.000	550.000	1750.000	4800.000

STATION CODE=Q20 CHANNEL BLW. BELMONT ST. DRAIN   DEPTH INTERVAL=SURFACE

VARIAB		N	MEAN	STD	MIN	P25	MEDIAN	P75	MAX
DISSOLVED OXYGEN	MG/L	10	8.650	0.636	7.800	7.800	8.850	9.125	9.500
TEMPERATURE	DEG. C	10	19.550	6.260	7.000	15.375	21.500	25.000	25.000
CONDUCTIVITY	UHOS/CM	12	205.417	9.405	190.000	200.000	210.000	210.000	220.000
ALKALINITY	MG/L	12	21.500	3.873	16.000	18.500	21.500	23.750	29.000
HARDNESS	MG/L	12	43.583	2.937	39.000	42.000	44.000	46.500	48.000
PH	STD. UNITS	12	7.292	0.151	7.000	7.200	7.300	7.400	7.500
CHLORIDE	MG/L	12	35.250	9.668	5.000	36.250	37.500	39.750	40.000

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                                   DATA SUMMARY BY STATION AND DEPTH
---------------------------- STATION CODE=Q20 CHANNEL BLW. BELMONT ST. DRAIN   DEPTH INTERVAL=SURFACE ----------------------------
         VARIAB                              N        MEAN         STD         MIN         P25      MEDIAN         P75         MAX

         SULFATE              MG/L          12      12.167       2.517       5.000      11.250      13.000      14.000      14.000
         IRON                 MG/L          12       0.070       0.099       0.000       0.022       0.050       0.067       0.370
         MANGANESE            MG/L          12       0.052       0.068       0.000       0.010       0.030       0.057       0.250
         TOTAL NITROGEN       MG/L          12       0.776       0.507       0.400       0.445       0.725       0.765       2.300
         TOTAL KJELDAHL N     MG/L          12       0.601       0.526       0.300       0.325       0.425       0.640       2.200
         ORGANIC N            MG/L          12       0.510       0.420       0.260       0.290       0.355       0.595       1.770
         AMMONIA-N            MG/L          12       0.091       0.123       0.000       0.012       0.030       0.157       0.430
         NITRATE-N            MG/L          12       0.175       0.114       0.000       0.100       0.150       0.275       0.400
         INORGANIC N          MG/L          12       0.266       0.155       0.010       0.112       0.295       0.377       0.530
         TOTAL P              MG/L          12       0.099       0.121       0.010       0.025       0.055       0.102       0.360
         TOTAL DISSOLVED P    MG/L          10       0.029       0.015       0.010       0.010       0.035       0.040       0.050
         SILICA               MG/L          12       1.408       1.449       0.000       0.025       1.000       2.925       3.700
         APPARENT COLOR       PT-CO UNITS   11      13.636       6.360       5.000      10.000      15.000      20.000      25.000
         TOTAL SOLIDS         MG/L          12     148.500      27.358     108.000     133.000     144.000     176.000     190.000
         SUSP.SOLIDS          MG/L          12       2.000       1.398       0.000       1.000       1.500       3.250       5.000
         TOTAL COLIFORMS      COUNTS/100 ML 10     301.000     187.821      30.000     105.000     340.000     450.000     600.000
         FECAL COLIFORMS      COUNTS/100 ML 10      53.500      33.254       5.000      27.500      50.000      90.000      90.000
         FECAL STREP          COUNTS/100 ML 10      12.600      10.319       5.000       5.000       7.500      20.000      36.000
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Appendix C

Data Summary by Lake and Depth Interval

Depth Categories:
Surface: Depth < 30 feet
Bottom : Depth >= 30 feet

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                                  DATA SUMMARY BY LAKE AND DEPTH INTERVAL

------------------------------------------- LAKE=FLINT   DEPTH INTERVAL=SURFACE ----------------------------------------------

VARIAB                                  N        MEAN         STD         MIN         P25      MEDIAN         P75         MAX

DISSOLVED OXYGEN    MG/L              205       8.829       1.709       3.700       7.800       8.700       9.800      14.400
TEMPERATURE         DEG. C            207      17.606       6.957       0.000      13.800      18.000      23.000      29.000
CHLOROPHYLL-A       MG/M3              30       4.313       1.998       0.810       2.910       3.740       5.400       9.550
TOTAL ALGAE         CELLS/ML           34    1221.523    1499.062     112.400     273.975     688.450    1594.675    7390.297
BLUE GREEN ALGAE    CELLS/ML           34     117.359     177.649       0.000       0.000      56.200      84.300     646.300
DIATOMS             CELLS/ML           34     850.438    1473.841       0.000       0.000     210.750    1046.725    6996.898
FLAGELLATES         CELLS/ML           34     163.641     136.697       0.000      77.275     126.450     252.900     646.300
GREEN ALGAE         CELLS/ML           34      90.085     117.149       0.000      28.100      56.200      91.325     477.700
CONDUCTIVITY        UHOS/CM           141     214.965      18.376     170.000     210.000     210.000     220.000     290.000
ALKALINITY          MG/L              141      24.028       3.372      15.000      22.000      24.000      25.500      39.000
HARDNESS            MG/L              141      45.277       3.897      34.000      44.000      44.000      48.000      64.000
PH                  STD. UNITS        141       7.340       0.240       6.200       7.200       7.300       7.400       8.200
CHLORIDE            MG/L              140      40.929       4.431      29.000      38.000      41.000      43.000      56.000
SULFATE             MG/L              132      12.530       2.731       5.000      11.000      12.000      14.000      21.000
IRON                MG/L              141       0.078       0.069       0.000       0.035       0.060       0.100       0.450
MANGANESE           MG/L              141       0.070       0.074       0.000       0.030       0.050       0.090       0.580
TOTAL NITROGEN      MG/L              141       0.784       0.338       0.270       0.560       0.700       0.920       2.450
TOTAL KJELDAHL N    MG/L              141       0.625       0.231       0.270       0.445       0.600       0.770       1.600
ORGANIC N           MG/L              141       0.568       0.227       0.170       0.395       0.570       0.695       1.410
AMMONIA-N           MG/L              141       0.057       0.043       0.000       0.030       0.050       0.070       0.250
NITRATE-N           MG/L              141       0.160       0.245       0.000       0.000       0.100       0.300       2.000
INORGANIC N         MG/L              141       0.217       0.265       0.000       0.050       0.160       0.300       2.250
TOTAL P             MG/L              140       0.049       0.027       0.010       0.030       0.040       0.060       0.140
TOTAL DISSOLVED P   MG/L               94       0.027       0.019       0.010       0.017       0.025       0.032       0.160
SILICA              MG/L              130       2.008       1.302       0.000       1.000       2.000       3.050       5.000
APPARENT COLOR      PT-CO UNITS       111      20.495       9.581       9.000      15.000      20.000      30.000      50.000
SECCHI DEPTH        FT                 24       6.575       1.637       3.900       5.050       6.750       7.900       9.200
TOTAL SOLIDS        MG/L              141     160.099      66.637      62.000     127.000     146.000     192.000     730.000
SUSP.SOLIDS         MG/L              141       2.801       1.653       0.000       2.000       2.500       3.500       8.000
TOTAL COLIFORMS     COUNTS/100 ML      96     108.906     185.991       5.000      20.000      40.000     120.000    1200.000
FECAL COLIFORMS     COUNTS/100 ML      96      13.333      24.416       5.000       5.000       5.000      10.000     160.000
FECAL STREP         COUNTS/100 ML      80       7.750      10.278       5.000       5.000       5.000       5.000      80.000

------------------------------------------- LAKE=QUINSIGAMOND   DEPTH INTERVAL=SURFACE ----------------------------------------

VARIAB                                  N        MEAN         STD         MIN         P25      MEDIAN         P75         MAX

DISSOLVED OXYGEN    MG/L              224       9.318       1.745       1.000       8.400       9.000      10.600      14.300
TEMPEPATURE         DEG. C            383      15.965       5.972       0.000      10.500      16.500      20.500      29.000
CHLOROPHYLL-A       MG/M3              52       5.167       2.039       2.030       3.425       4.775       6.955      10.380
TOTAL ALGAE         CELLS/ML           56    2405.542    3207.877     281.000     550.225     899.200    2423.625   12575.398
BLUE GREEN ALGAE    CELLS/ML           56     274.979     358.445       0.000      56.200     154.550     358.275    1854.600
DIATOMS             CELLS/ML           56    1903.273    3241.706       0.000      56.200     393.400    1454.175   12448.297
FLAGELLATES         CELLS/ML           56     161.686     168.364       0.000      56.200     112.400     189.675     814.900
GREEN ALGAE         CELLS/ML           56      67.962      79.620       0.000       0.000      28.100     112.400     309.100
CONDUCTIVITY        UHOS/CM           143     195.874      23.812     120.000     190.000     200.000     210.000     320.000
ALKALINITY          MG/L              143      21.566       2.845      15.000      20.000      21.000      23.000      33.000
HARDNESS            MG/L              143      41.827       4.240      21.300      41.000      42.000      44.000      61.000
PH                  STD. UNITS        143       7.292       0.235       6.600       7.100       7.300       7.400       8.300
CHLORIDE            MG/L      [illegible]  [illegible]  [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]
SULFATE             MG/L              133      12.160       2.619       3.000      11.000      13.000      14.000      16.000
IRON                MG/L              143       0.107       0.164       0.000       0.030       0.060       0.100       1.500
MANGANESE           MG/L              143       0.044       0.053       0.000       0.020       0.020
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DATA SUMMARY BY LAKE AND DEPTH INTERVAL

LAKE=QUINSIGAMOND   DEPTH INTERVAL=SURFACE

VARIAB		N	MEAN	STD	MIN	P25	MEDIAN	P75	MAX
TOTAL NITROGEN	MG/L	143	0.783	0.376	0.220	0.490	0.720	0.910	2.380
TOTAL KJELDAHL N	MG/L	143	0.576	0.303	0.090	0.380	0.500	0.710	1.800
ORGANIC N	MG/L	143	0.517	0.279	-0.390	0.350	0.460	0.640	1.570
AMMONIA-N	MG/L	143	0.059	0.092	0.000	0.010	0.030	0.070	0.700
NITRATE-N	MG/L	143	0.207	0.218	0.000	0.000	0.200	0.300	2.000
INORGANIC N	MG/L	143	0.266	0.246	0.000	0.090	0.260	0.410	2.030
TOTAL P	MG/L	142	0.079	0.098	0.010	0.030	0.040	0.072	0.490
TOTAL DISSOLVED P	MG/L	103	0.026	0.016	0.000	0.010	0.030	0.040	0.080
SILICA	MG/L	134	1.246	1.931	0.000	0.175	1.000	1.800	20.000
APPARENT COLOR	PT-CO UNITS	124	16.343	11.408	0.000	5.000	15.000	25.000	50.000
SECCHI DEPTH	FT	59	8.358	2.949	4.600	5.900	7.500	10.600	15.800
TOTAL SOLIDS	MG/L	143	151.238	49.036	18.500	124.000	140.000	188.000	314.000
SUSP.SOLIDS	MG/L	143	1.927	1.405	0.000	1.000	2.000	3.000	6.000
TOTAL COLIFORMS	COUNTS/100 ML	104	146.010	255.542	5.000	20.000	50.000	180.000	2200.000
FECAL COLIFORMS	COUNTS/100 ML	104	27.404	57.450	5.000	5.000	10.000	23.750	480.000
FECAL STREP	COUNTS/100 ML	104	10.385	14.610	5.000	5.000	5.000	10.000	120.000

LAKE=QUINSIGAMOND   DEPTH INTERVAL=BOTTOM

VARIAB		N	MEAN	STD	MIN	P25	MEDIAN	P75	MAX
DISSOLVED OXYGEN	MG/L	293	4.629	3.960	0.000	0.500	4.400	7.950	13.900
TEMPERATURE	DEG. C	503	7.551	1.420	5.000	7.000	7.500	8.000	15.500
CONDUCTIVITY	UHOS/CM	107	221.355	18.140	190.000	210.000	210.000	230.000	270.000
ALKALINITY	MG/L	107	30.944	11.197	18.000	23.000	27.000	36.000	64.000
HARDNESS	MG/L	107	45.430	3.564	40.000	42.000	45.000	48.000	56.000
PH	STD. UNITS	107	7.068	0.263	6.500	6.900	7.000	7.300	7.700
CHLORIDE	MG/L	107	40.308	3.196	24.000	38.000	40.000	43.000	47.000
SULFATE	MG/L	103	11.262	4.019	2.000	9.000	12.000	13.000	26.000
IRON	MG/L	107	2.351	3.889	0.000	0.190	0.500	2.000	16.000
MANGANESE	MG/L	107	1.304	1.146	0.010	0.450	0.990	2.000	4.500
TOTAL NITROGEN	MG/L	107	1.440	1.047	0.410	0.950	1.130	1.600	9.500
TOTAL KJELDAHL N	MG/L	107	1.105	0.789	0.260	0.540	0.870	1.400	3.900
ORGANIC N	MG/L	107	0.384	0.360	-0.530	0.150	0.290	0.480	1.680
AMMONIA-N	MG/L	107	0.721	0.874	0.030	0.160	0.330	0.800	3.700
NITRATE-N	MG/L	107	0.335	0.771	0.000	0.100	0.300	0.400	8.000
INORGANIC N	MG/L	107	1.057	1.109	0.030	0.530	0.690	0.960	9.100
TOTAL P	MG/L	107	0.166	0.203	0.010	0.040	0.070	0.230	0.910
TOTAL DISSOLVED P	MG/L	85	0.096	0.123	0.000	0.020	0.040	0.135	0.550
SILICA	MG/L	101	4.036	2.172	0.200	2.550	3.500	4.950	11.000
APPARENT COLOR	PT-CO UNITS	93	32.866	28.202	0.000	15.000	20.000	37.500	100.000
TOTAL SOLIDS	MG/L	107	145.774	30.176	17.800	136.000	142.000	156.000	224.000
SUSP.SOLIDS	MG/L	107	2.585	2.165	0.000	1.000	2.000	3.500	11.000

APPENDIX D

SOIL DESCRIPTIONS

SOIL DESCRIPTIONS*

The major soil association of the Lake Quinsigamond watershed is the Paxton-Hollis-Canton association. Detailed descriptions of these soils are presented below:

Paxton Series - These are well drained soils which develop from stony, compact till derived largely from schist and gneiss. Surface soil, subsoil, and substratum are generally a fine sandy loam. The permeability of the surface soils and subsoil is moderately rapid or rapid, but the Paxton soils have a slowly permeable hardpan at about two feet. They occur on nearly level to very steep slopes.

Hollis Series - These are somewhat excessively drained, shallow to bedrock soils that have formed in the deposits of glacial till derived from schistose and granitic material. They have a fine sandy loam surface soil and subsoil. Depth to bedrock is generally within 2 feet of the surface. Bedrock outcrops vary from less than 10 feet to more than 100 feet apart. They occur on gentle to very steep slopes.

Canton Series - These are well drained soils which formed over a gravelly, loamy, sandy, till derived from granite and gneiss. They developed into sandy loam. The permeability is moderately rapid or rapid in the fine sandy loam surface soil and rapid in the gravelly, loamy sand substratum. They occupy nearly level to steep slopes.

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*Descriptions of soils are from the United States Department of Agriculture, Soil Conservation Service, Holden, Massachusetts.